Volume 6, No. 2 **April 1951**

The Water Situation in the United States

Sediment Steals Water Storage

The Wrong Turn

What Determines the Value of Water

The Soil Under Natural and Cultural Environments

Terrace Drainage of Almena Soils in Central Wisconsin

20 Million More Mouths to Feed by 1960?

ALL CONSERVATIONISTS are keenly aware of the immediate need for increased food production; particularly the products of animal agriculture—so essential to the success of our national defense program.

At the same time, they have not lost sight of future needs that must be met. Based on the steady growth of our population, there may well be 170 million mouths to feed within the next decade. This will dictate an even higher percentage of increase in our livestock population . . . to match the ever-growing trend to a high-protein diet.

Recognizing this dual responsibility, most conservationists are placing even greater emphasis on grassland farming. They know that keeping America the best-fed nation makes it doubly important to follow a sound soil-building program: (1) by *keeping* more acres in deep-rooted legumes and grasses and (2) handling them by tried and proved methods that insure increasing productivity through *soil building*.

Forward-looking manufacturers of farm machinery are no less conscious of the two-fold importance of advancing the cause of grassland farming. This is particularly true at NEW IDEA, where the development of new and better machines for handling forage crops is a never-ending assignment.

NEW IDEA
DIVISION AVCO MANUFACTURING CORPORATION
Coldwater, Ohio

that's why a **NEW IDEA** *is a good idea!*

Illustrated literature describing individual NEW IDEA Haying Machines and other specialized equipment in the NEW IDEA line is yours for the asking. Address your request to Dept. 150.

The *best* soil is the first to run away...

but most of it can be kept at home with McCormick farm equipment

Experiments conducted at Rutgers University indicate that surface soil runoff contains about five times as much nitrogen and organic matter as the soil that's left in the field. It's easy to understand how rich topsoil, which hoards so much plant food, is coaxed away from home by rains that don't budge heavy clay.

These tests demonstrate that farmers who delay soil conservation practices until they see erosion scars have waited too long. They've already been robbed!

This loss can easily be avoided. McCormick Farmall tractors and McCormick farm implements make terrace building, contour cultivation, and other soil-saving techniques both practical and profitable. Thousands of farmers are using this modern power equipment to keep their richest soil at home where it can help produce the food, feed and fiber needed to keep America strong. International Harvester Company, Chicago 1, Illinois.

This farmer is maintaining terraces with a Farmall M tractor and a McCormick two-furrow moldboard plow.

INTERNATIONAL HARVESTER

International Harvester Builds McCormick Farm Equipment and Farmall Tractors . . . Motor Trucks . . . Crawler Tractors and Power Units . . . Refrigerators and Freezers

MORE "Muscles of Steel" ON THE FARM HELPS WIN THE BATTLE OF CONSERVATION, TOO

Farming, with its specialized production of food, fat, and fibre, really came into its own when modern machinery became available to farmers.

So, too, did modern conservation practices.

The "steel muscles" of Ferguson Tractors and the more than 60 Ferguson Implements provide farmers with the tools they need to build terraces, farm ponds, and install land use measures . . . guardians of precious soil and water. The light weight of this equipment helps prevent soil packing and the creation of compacted and poorly drained soil layers. Yet the power and flexibility of Ferguson Equipment with its lighter weight permit the farmer to apply his conservation plan easily, and with a minimum of time and effort.

More than ten years ago, one of the major goals of the Ferguson organization was established—helping farmers win the battle of conservation. And every piece of equipment developed by Ferguson in that time was designed with this goal in view.

If you are interested in more facts about Ferguson Equipment and how it helps the Soil Conservation Program through better farm practices, please write.

HARRY FERGUSON, INC.,
Dept. JC, 3639 E. Milwaukee Ave.
Detroit 11, Michigan

HIGH LIGHTS

- Over a half million tractors incorporating the Ferguson System sold since 1939.
- A broad line of over 60 quality engineered implements for virtually every farming need.
- Ferguson Tractor now produced in "World's Most Modern Tractor Assembly Plant" at 72-acre Ferguson Park, Detroit, Michigan, and in Coventry, England.
- Distribution in over 65 countries throughout the world.
- Rapidly expanding dealer organization with some desirable territories still available.

Copyright 1951 by Harry Ferguson, Inc.

FERGUSON TRACTOR and FERGUSON SYSTEM IMPLEMENTS

1,000,000,000 POUNDS OF SEED

To save the soil and to produce the ever-increasing tonnage of meat and milk our steadily growing population requires, American farmers need a yearly 1¼ billion pounds of grass, legume, and other forage seeds, according to USDA estimate. New full-color 24x36-inch poster, "MONEY CROPS . . . NEW AND OLD," illustrates many of these crops, some familiar, some little known. It gives tips on how to save as much of the seed as possible, outlines the characteristics a combine should have to fit the job. Colorful, interesting, educational. Available without charge.

CASE

POSTERS • CHARTS • BOOKLETS • SLIDE FILMS • FULL-COLOR SOUND MOVIES

You have your choice of a wide variety of subjects and media among Case Visual Education Materials. Big, bright posters and charts which illustrate contouring, building ponds and terraces, farm safety, and farm machinery, to name a few.

Slide films show farming history, safety, proper operation of farm machinery, and other topics. Study-outlines cover pond building, contour and grassland farming. Movies and companion booklets teach conservation, range management, profitable farm production, theory and application of tractor hydraulic controls. All contain little or no advertising.

Printed matter is furnished, slide films and movies loaned—all without charge. Movies are all 16 mm., in color with sound. Order booklets and schedule films through your Case dealer or branch, or Educational Division, J. I. Case Co., Racine, Wis.

Send for Case Visual Education Materials Catalog. This handy little booklet lists and describes all movies, posters, etc., tells how to order printed matter, how to schedule films. It is a big help in planning interesting teaching and lecture schedules. Address your request to the Racine office. There is no charge for this material and service.

Journal of SOIL AND WATER CONSERVATION

VOLUME 6
NUMBER 2

OFFICIAL ORGAN OF THE SOIL CONSERVATION SOCIETY OF AMERICA

This JOURNAL is owned, edited, and published quarterly by the Soil Conservation Society of America.

OFFICERS AND COUNCIL
OF THE S.C.S.A.

MORRIS E. FONDA ..... *President*
AUSTIN L. PATRICK ..... *First Vice President*
G. M. BROWNING ..... *Second Vice President*
ROGER H. BRAY ..... *Council*
J. C. DYKES ..... *Council*
KIRK FOX ..... *Council*
EDWARD H. GRAHAM ..... *Council*
RUSSELL G. HILL ..... *Council*
R. H. MUSSER ..... *Council*
J. K. VESSEY ..... *Council*
F. A. WIRT ..... *Council*
FIRMAN E. BEAR ..... *Council*

Secretary
ALVIN C. WATSON
Room 411, Center Building
Upper Darby, Penna.

Treasurer
WARREN C. HUFF
8 East Long Street
Columbus 15, Ohio

PUBLICATION OFFICE: 32nd Street and Elm Avenue, Baltimore 11, Maryland.

NATIONAL HEADQUARTERS AND SECRETARY'S OFFICE: Room 411, Center Building, Upper Darby, Penna.

POST OFFICE ENTRY: Entered as Second-Class matter in the Post Office at Baltimore, Maryland, August 28, 1946, under the Act of March 3, 1879.

MEMBERSHIP: Annual membership is on a calendar year basis and is $5.00 per year for members and $3.00 per year for associate members, of which $1.50 is for subscription to the JOURNAL and 25c for NOTES AND ACTIVITIES. Subscriptions for the JOURNAL to libraries and others is $3.00 per year. Single copies are 75c each.

CORRESPONDENCE—Concerning manuscripts, books for review and other editorial matters should be sent to the Editor, Room 608, Watson Building, Fairmont, West Virginia.

BUSINESS CORRESPONDENCE—Concerning remittances and questions should be sent to the Secretary, Room 411, Center Building, Upper Darby, Penna.

CHANGE OF ADDRESS: Notice of change in address should be received two weeks before the date of issue on which the change is to take effect. Both the old and the new address should be sent to the office of the Secretary.

REPRINTS: Articles appearing in this publication may be reprinted on condition that full credit be given the JOURNAL OF SOIL AND WATER CONSERVATION and the author; also the date of publication.

Contents for April, 1951

From the Editor 62

The Soil Under Natural and Cultural Environments 63
ROY W. SIMONSON

Terrace Drainage of Almena Soils in Central Wisconsin 70
A. J. WOJTA, C. B. TANNER, AND R. J. MUCKENHIRN

The Wrong Turn 75
FIRMAN E. BEAR

The Water Situation in the United States 78
JOSEPH V. B. WELLS AND ADRIAN H. WILLIAMS

Pictorial Section 83

What Determines the Value of Water? 87
GEORGE D. CLYDE

Sediment Steals Water Storage 92
CARL B. BROWN

Recent Research Reviews 99
JAMES H. STALLINGS

Book Reviews 101

Field Notes and Comments 108

COVER. Daffodils planted on the contour in the Van Hevelingen Nursery, Oregon. Extensive erosion occurred on this land in previous years. Since then, however, bulbs planted on the contour, have practically controlled erosion. The entire nursery is under a complete conservation plan. (*Photo by Dale Swartz*).

EDITORIAL OFFICE: ROOM 303 WATSON BUILDING
FAIRMONT, WEST VIRGINIA

WALTER C. GUMBEL, *Editor*

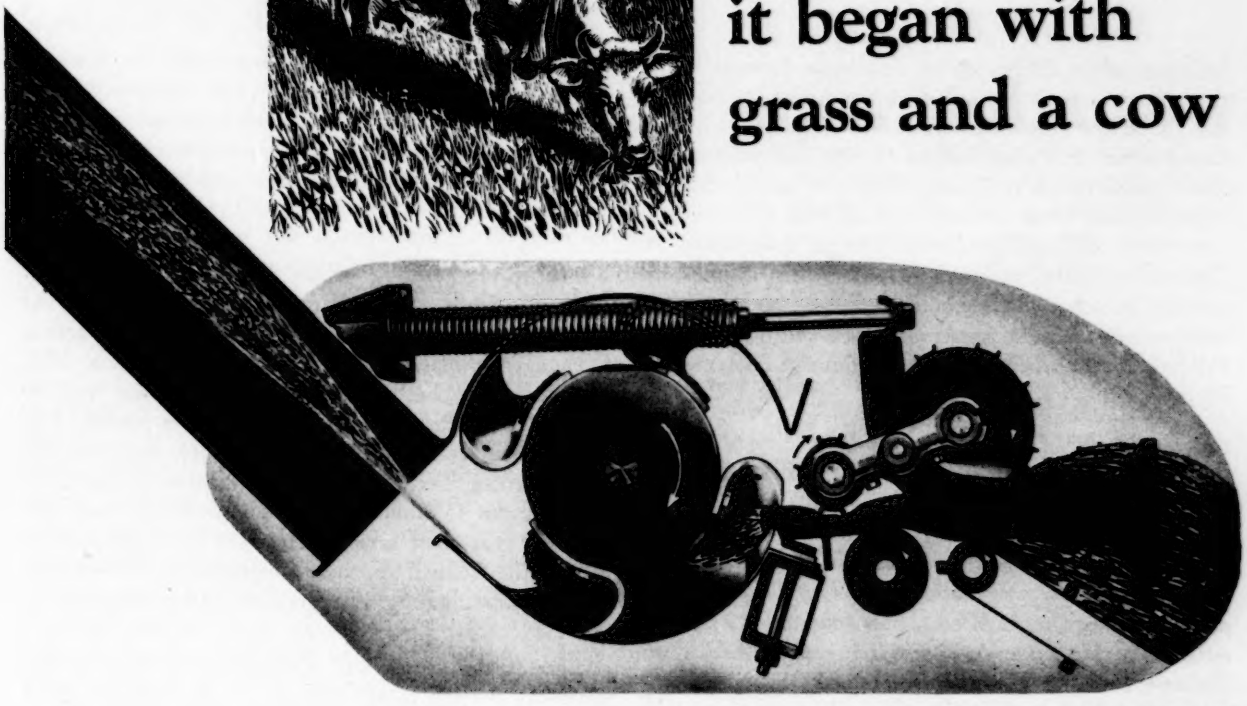
EDITORIAL BOARD

Term Expiring 1951
EDWARD H. GRAHAM, *Falls Church, Virginia*
ORVILLE E. HAYS, *La Crosse, Wisconsin*
E. L. SAUER, *Urbana, Illinois*

Term Expiring 1952
BEN O. OSBORN, *San Angelo, Texas*
A. D. STOESZ, *Lincoln, Nebraska*
ROGER H. BRAY, *Urbana, Illinois*

Term Expiring 1953
CARL B. BROWN, *Washington, D. C.*
WM. R. VAN DERSAL, *Portland, Oregon*
BERNARD FRANK, *Washington, D. C.*

it began with grass and a cow



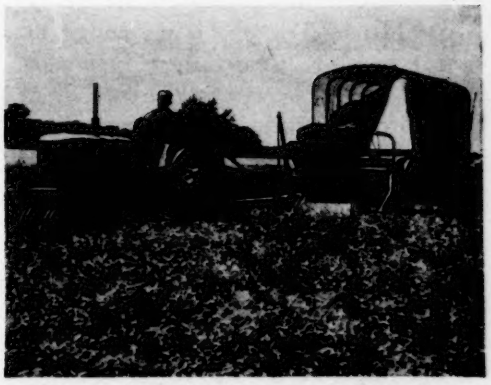
"Inside Story." Side view of A-C Forage Harvester's feeding and chopping system. Feed rolls (right) control incoming material to within two inches of shear-bar. Spiraled, cup-shaped knives of chopping cylinder shear and chop cleanly across full 36-inch width.

HOW to have choice green feed the year 'round — that has been one of the basic problems in keeping sod on the land without restricting the farmer's income. One of the ways Allis-Chalmers set out to meet this need was in the development of a completely new Forage Harvester.

Engineering started in the field and stayed in the field until many problems were answered—including such tough ones as big capacity without big power demands . . . adaptability to standing hay crops, row crops and windrows . . . protection against rocks . . . and easy, uniform sharpening of all cutting knives.

A critical inspection of the A-C Forage Harvester will disclose an outstanding example of the way agricultural engineering finds better answers to old problems — with design which begins in the field with basic needs and ends with agricultural machines that combine outstanding performance with simplicity, easy operation and reasonable cost.

The Allis-Chalmers Forage Harvester is a 3-in-1 machine, for standing grass crops, row crops and windrows.



Listen to the National Farm and Home Hour — Every Saturday — NBC

ALLIS-CHALMERS

TRACTOR DIVISION • MILWAUKEE 1, U. S. A.

From The Editor

Conservation Education in American Schools is the title of a new book published by the American Association of School Administrators. It is not a text book on conservation, or a compendium of technical information about conservation practices. Rather, it is an administrator's guide which defines a broad area of school responsibility and indicates what can be done about it. Challenges, guides, practices, materials and facilities are outlined in ways which should be helpful to school administrators, teachers, conservationists, and others in expanding and improving school programs of conservation education.

The book may be obtained from the National Educational Association, 1201 Sixteenth Street, Northwest, Washington 6, D. C. The price per copy is $4.00.

The Michigan Chapter of the Soil Conservation Society of America in cooperation with The Kellogg Company of Battle Creek, Michigan, is sponsoring a contest on soil and water conservation. It is called "A Plan to Conserve Soil and Water Resources in a Michigan Community," *and is open to any undergraduate student regularly enrolled in a Michigan College or University. The plan may consist of (a) an essay, not exceeding 2500 words, which explains the plan, (b) an outline for teaching soil and water conservation in any part of a school curriculum or to youth groups (4-H Club, Boy Scouts, F.F.A.) or (c) an action program in a community.*

Awards totaling $830 will be presented to the winners at the annual banquet of the Michigan Chapter late this fall.

Sir Harold Tempany is the author of an excellent article entitled *"Conservation Legislation"* which appeared in the December 1950 issue of WORLD CROPS published in England. The author points out that legislation to insure proper land use has been enacted in many countries and is contemplated in others—thereby showing the extent to which public opinion has been awakened. Conservationists interested in the world problem of erosion will find this paper stimulating and informative.

The July issue of the JOURNAL *will contain a new section devoted to conservation programs and related developments in Mexico, Central and South America. Fernando Suarez De Castro, an active member of the Society in Columbia, has agreed to assemble the material for each issue. It will cover all the Spanish-speaking countries in Latin-America. This will undoubtedly place the Society in a much stronger position to be more helpful in developing a comprehensive conservation program for the Americas.*

The spring meeting of the SCSA Council held at Jackson's Mills, West Virginia, clearly indicated to those in attendance that members everywhere are actively engaged in many constructive Society activities. This includes work that is being done in chapters and by committees at the national level. Reports presented to the Council from the Emblem, Glossary, Business and Organization, Technical, Chapter Activities, and Society Program Committees were comprehensive and emphasized immediate action. President Fonda and members of the Council are to be congratulated for their efforts in promulgating an aggressive Society program.

The "Field Notes and Comments" section of the JOURNAL is open to all members of the Society. Brief items based on member experiences relating to soils, hydrology, wildlife, conservation education, research in all fields, forestry, crops, and other phases pertaining to land use are needed. The items should not exceed 300 words and may be illustrated. Members of the Society are also urged to be on the lookout for quality photographs for the pictorial section and cover. Cutlines should be complete and tell a positive conservation story. Material submitted for inclusion in the July issue should reach the editor on or about June 1.

Inquiries from advertisers and advertising agencies regarding space in the JOURNAL *are increasing. Because of this interest, two additional pages are scheduled for the July issue. It is possible that an additional page or two may be added between now and the date of publication. Readers, when writing to advertisers, should mention the advertisements which appear in the* JOURNAL. *This is highly important. S. S. Visher of Bloomington, Indiana, in commenting on the excellence of the Book Review section ordered five books. It would be interesting to know if others could report similar expriences.*

"Every man owes a part of his time to the up-building of the profession to which he belongs."—Theodore Roosevelt.

The Soil Under Natural and Cultural Environments

ROY W. SIMONSON

This paper by Dr. Simonson describes a few of the great soil groups with comments on the shifts that follow their use. Soils tend to become different in their natural environment. Under the cultural environment imposed by man, the difference among the soils and soil groups are reduced. We tend to lower fertility levels in the richest soils and raise them in the poorest soils. Organic matter contents are lowered in some soils and raised in others. On the whole, we make more changes in chemical properties than in physical proprties.

MOST PEOPLE REALIZE that soils differ from farm to farm, from county to county, and often from one part of a field to another. The nature of these differences is not so commonly known nor is it well known that the soil at any given spot consists of a number of layers roughtly parallel to the land surface. We see the surface layers and often overlook the deeper ones though the latter may be more important than what we see. Our interest in soils stems from the fact that they support most of the plants used for food, fibre, or shelter. The roots of plants commonly penetrate to depths of several feet and hence, the nature of soil profile to some depth affects its usefulness. Furthermore, when the soil is used in one way or another, it is changed either for better or for worse.

How and Why Soils Differ

First of all, let us look at the soil in a few places. If we were to dig a pit several feet deep in one of the few remaining prairie areas in eastern Iowa, we should find a succession of layers extending down from the surface. The uppermost 12 to 18 inches is a dark, crumbly, and granular layer. It grades into a lighter colored, more sticky and plastic layer of about the same thickness. Below that, we commonly find a light yellowish brown horizon, often marked with a few faint splotches or mottles. This profile, characteristic of Prairie Soils, is shown in Figure 1, a photograph of Tama silt loam. This is how the soils appear over a large part of the undulating uplands in the heart of the Corn Belt.

Roy W. Simonson presented this paper at the Annual Meeting of the Southern New England Chapter of the Soil Conservation Society of America, held at New Haven, Connecticut, October 20, 1950. Mr. Simonson is Assistant Chief, Division of Soil Survey, Bureau of Plant Industry, Soils and Agricultural Engineering, Agricultural Research Administration, U. S. Department of Agriculture, Beltsville, Maryland. In preparing this manuscript, the author has drawn freely from a paper *"The Influence of Man on the Soil"* by Guy D. Smith.

If we now step over to a nearby area where forest was the native vegetation, we shall find a soil with a different succession of horizons, as shown in Figure 2. The mellow dark colored surface layer is now only an inch or two thick. Beneath it is a light brownish gray horizon, six to 12 inches thick, which breaks down into small fragile platy pieces. Below this light colored horizon is a much thicker, darker, and stickier horizon that breaks out into irregular small blocks. These blocks are hard when dry and very sticky when wet. This horizon is much higher in clay than the ones above. Below the darker horizon with its blocky structure is a fourth horizon, which is usually light yellowish brown in color and may be splotched or mottled with patches of other colors. Fayette silt loam, shown in Figure 2, has been formed from exactly the same loess as Tama silt loam but under forest rather than grass vegetation. Both soils may occur on the same ridge and I have looked at them where they were less than a half mile apart. The two soils provide striking illustrations of the effects that vegetation may have in soil formation. The differences also serve to emphasize the fact that soils take on different properties as they develop in the natural environment.

Now let us move somewhat further and stop to look at a soil from sandy glacial till in Maine. If we dig a pit in a forested area where the trees are mainly cone bearing species, we shall find a soil with a fairly thick surface layer of organic matter in various stages of decay. Recognizable needles, twigs, and the like cover the surface and those merge downward into the rotted remains of earlier leaf falls. This layer of organic matter is usually set apart sharply from the uppermost layer of mineral matter, a light gray, often sandy, horizon anywhere from one to six inches thick. These two horizons and even part of the next deeper one are mixed when the land is cleared and cultivated. The surface layer of organic matter also disappears when fire goes through the forest. Consequentlv, these two horizons

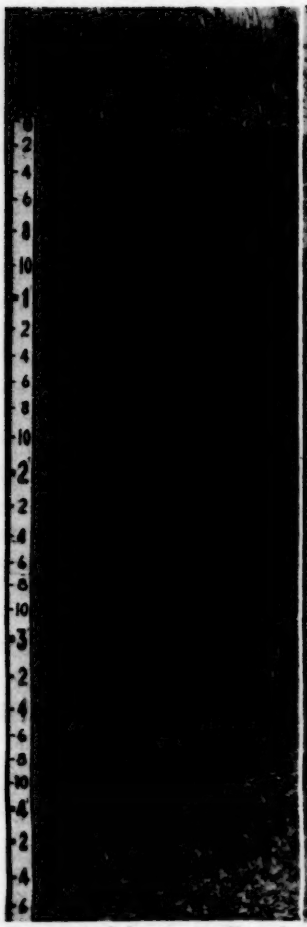


Figure 1 *left*—A profile of Tama silt loam, a Prairie soil from loess. This shows the three main horizons and the gradation from one to the other.

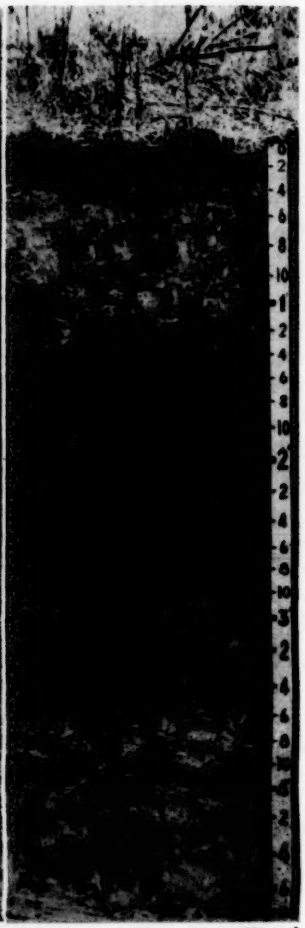


Figure 2 *right*—A profile of Fayette silt loam, a Gray-Brown Podzolic soil from loess. This shows the very thin dark surface horizon, a thicker light-colored horizon, and a second dark horizon above the leached loess.

are often obscure in the soils as they now exist. The deepest horizons are still readily identified. however, as a general rule. Under natural conditions, there is a brown, often coffee-colored, layer six to twelve inches thick immediately beneath the light colored leached horizon. The color reflects an accumulation of iron oxides, more commonly known as iron rust. Below the zone of iron oxide accumulation is a lighter colored layer consisting of geologic material similar to that from which the soil is formed. This soil, illustrated by Brassua sandy loam in Figure 3, is characteristic of the belts of coniferous forest in Canada and in the northern United States, Asia, and Europe.

Over the years, soil scientists have concluded from observations made in many places that soils generally have profiles made up of a succession of layers or horizons. Furthermore, they have observed again and again the relationships between the nature and arrangement of these horizons and the character of the vegetation, slope and climate. These relationships have lead scientists to conclude that the character of soil is determined by (1) Climate, through the effects of sunshine, rain, frost, and wind; (2) Parent material, the stuff from which soils are formed; (3) Topography, or lay-of-the-land; (4) Living organisms, such as vegetation, animals, and man; and (5) Time, the interval during which these factors have been operating. It is seldom possible to be fully certain about the effect of any one factor in the formation of a soil. The influence of each factor depends a great deal upon its combination with the others. With the variety of climates, geological materials, kinds of topography, types of vegetation, and ages of land surfaces in the world or even within the United States, there are many, many different combinations of these factors of soil formation. Because of the large number of combinations, there are a great number of specific soils or soil types. Differences among them may be great, as between Tama silt loam and Brassua sandy loam, or they may be small as they are between Tama silt loam and other Prairie soils. Because of the similarities and differences in soil types, it is possible to classify them into groups. The most useful basis for classification of soils found thus far has been the kind and arrangement of horizons or layers that make up the soil profile.

Great Soil Groups

As men studied soils, they noticed that there were a number of similarities in the kind and arrangement of horizons in the soils of regions over which the factors of formation are similar although not entirely identical. These soils can then be classified together into broad groups so that each specific soil in that group has the same kinds and arrangement of horizons, although there are differences in a number of soil properties within the group. Such broad classes are called Great Soil Groups and are roughly comparable to an Order in the classification of plants or animals. The general pattern of Great Soil Groups in the United States is shown in Figure 4. This map is on a small scale and consequently must be generalized. Many individual small areas of great soil groups cannot be shown. Only the broad patterns can be indicated on a small map. Even this map, however, will suggest to you immediately the great diversity among soils under natural conditions. Further understanding of those differences can be gained by study of a few examples of the Great Soil Groups.

Desert Soils—If we were to start at the foot of the Rockies in central Wyoming and travel eastward, we would first cross the Desert and Sierozem soils, one of several belts that run north and south in the Great Plains. These soils are formed under a climate so dry that they support an incomplete stand of vegetation. Because the plant growth is scanty, the soils are low in organic matter. Because there is little rain, soluble plant nutrients such as calcium and potassium are not washed out of the soils. Moreover, the soils are not strongly weathered and contain minerals which are still high in reserves of plant nutrients. Even so, these soils are of little value to mankind under natural conditions. They provide seasonal grazing but they have not supported stable civilizations without changes from the natural environment. To use these soils, man changes them by adding water through irrigation and by adiding fertilizers carrying nitrogen and phosphorus. As the soils are used under irrigation, the content of organic matter is increased and the structure is often improved. Thus, the Desert soils are more productive in the cultural than in the natural environment.

Brown Soils—The next belt to the east, one of which average rainfall is somewhat higher, is that of the Brown Soils. The grasses grow better in this region but are still unable to cover the surface of the soil completely. The rainfall is not yet great enough to dissolve and leach out important quantities of nutrients such as calcium and potassium. Neither is the rainfall dependable enough for safe cultivation and hence the Brown Soils are a transition zone from grazing to the growing of wheat. They are largely used for grazing but in years of high rainfall Brown Soils have produced large crops of wheat. Because of these occasional "good years," the soils are cultivated too often and grazed too heavily. The famous "dust bowl" of the Southern Great Plains is in the region of the Brown Soils. Thought to have been destroyed by the tremendous dust storms of the thirties, the "dust bowl" has produced bumper crops during the last decade. Yet as the cycle continues, we can expect that drought will come again to the Great Plains and that dust will blow again. There is good evidence that dust storms did occur under natural conditions but were less severe than those which have followed extensive cultivation of Brown soils. Problems in the use of Brown soils, however, are economic rather than agronomic. As long as a single wheat crop is worth more than the cost of the land, men are going to try to farm the soils from time to time with hopes of hitting the jackpot. As long as a couple of good crops can bring more money than many farms in the United States are worth, men will gamble on the weather and cultivate Brown soils that should be left in grass.

Figure 3—A profile of Brassua sandy loam, a Podzol from granitic glacial till. This shows the mat of organic matter, the light gray horizon beneath it, and the second darker horizon above the leached till. (*Photograph by Charles E. Kellogg*)

Prairie Soils—Moving on to the east, let us skip the belts of Chestnut soils and Chernozems and go on to the Prairie soils of the Corn Belt. These soils, illustrated by Tama silt loam in Figure 1, are much like the Chernozems but were formed under higher rainfall and have thus lost larger amounts of nutrient elements such as calcium, magnesium, and potassium through leaching. Grasses have grown on the soils for centuries, so that contents of organic matter are high and extend to unusual depths. The rainfall has been able to remove enough of the soluble calcium to make the soils more acid than optimum for crop production and crushed limestone is therefore generally used. Because of high fertility levels of the virgin soils, however, few fertilizers have been used on the Prairie soils. With a combination of favorable rainfall and high levels of fertility, the region of Prairie soils has been the bread basket of the nation. No area of comparable size and productivity is know to occur elsewhere in the world.

The levels of fertility and of organic matter under the natural environment were so high that it was impractical to maintain them in the new cultural environment. Farmers therefore have been and are accused of exploiting the soils. This has certainly been true in the past—and it was the proper thing to do. A part of the large store of fertility was certainly much more useful to the people in the Corn Belt after it was converted into homes, schools, roads, and the like than it could hae been locked up in the soil.

Areas of Prairie Soils have not all been well handled in the past, and many have therefore suffered from depletion and erosion. Part of this has been justified, but part of it was not. The erosion is a waste of natural resources inasmuch as the surface horizons contain large quantities of nitrogen and organic matter. Past erosion has not reduced the productive capacity of Prairie soils generally but it does increase the cost of production. On the other hand, erosion has reduced permanently the productive capacity of some Prairie soils under farming methods now known. The Prairie soils in which deeper horizons are very high in clay are permanently damaged by removal of the surface layers. Fortunately, these soils are a small part of the total region dominated by the Prairie group. Beyond that, increasing attention has been given to the fertility status of the Prairie soils and it may well be that the trend of the past no longer contiues. It seems that a few of the Prairie soils have been improved under cultivation though this is uncommon. More attention to the maintenance of fertility levels and the control of erosion will be necessary in the future than has been true in the past. In spite of that, however, we can expect that the Prairie soils will not regain what was lost in shifting from a natural to a cultural environment.

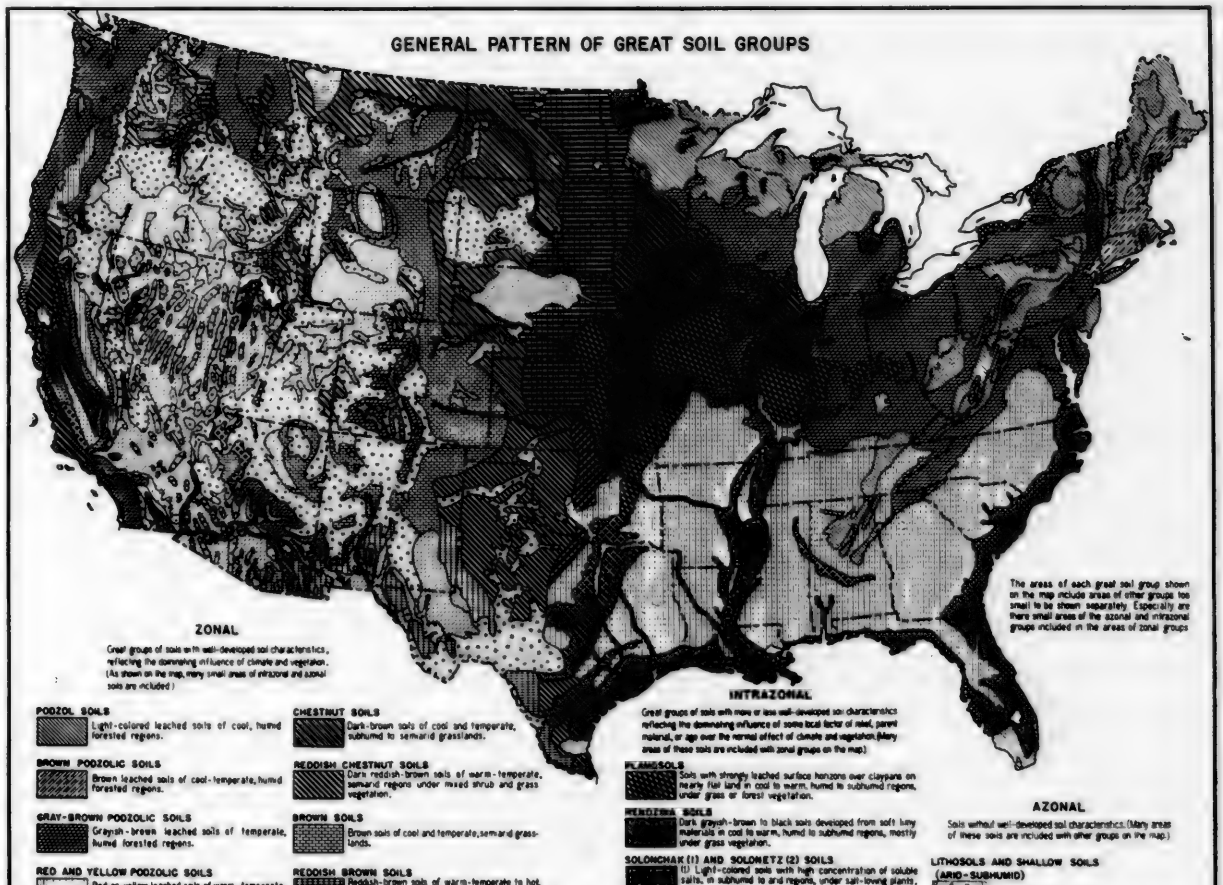
Gray-Brown Podzolic Soils—If we now resume our journey eastward, we shall leave the grasslands and enter the oak-hickory forest zone in a region sometimes called the Little Corn Belt. This region is dominated by Gray-Brown Podzolic soils, illustrated by Fayette silt loam in Figure 2. Tongues of these soils extend along the main streams into the regions of Prairie soils. Those formed under forest lack the thick dark surface horizon high in organic matter. The trees are less effective in adding nitrogen to the soil and also permit greater leaching of nutrient elements such as calcium, potassium, and phosphorus. As a consequence, the Gray-Brown Podzolic soils are more acid and have lower contents of organic matter except in the uppermost inch or two. This layer is mixed with lighter colored horizons beneath when the soil is first plowed and thus disappears.

Our western civilization has developed largely in regions dominated by Gray-Brown Podzolic soils both in western Europe and in the eastern United States. The people of western Europe learned long ago that the soils must be manured and fertilized for satisfactory crop production. Yields on these soils in western Europe have been slowly rising for the last several centuries. The increased yields are doubtless due in part to improvements in crop varieties and the like, but the evidence seems clear that the Gray-Brown Podzolic soils have been improved on the whole in a cultural environment. The fertility levels are higher now than they were in virgin soils. Erosion has been moderate on these soils generally in the United States, with effects that differ from one soil to another. Where the deeper horizons are not too high in clay, Gray-Brown Podzolic soils can be productive after erosion of the surface horizons. As with the Prairie soils, however, costs of production are increased slightly when the surface soil is lost. Furthermore, the soils with large amounts of clay in the deeper horizons are not suitable for crop production once they have been eroded. Taking the soil group as a whole, however, the productive capacity is greater now under use by mankind than it was in the original forest.

Podzols and Brown Podzolic Soils—If we look again at the map of the United States, we will see that the belts east of the Mississippi River no longer run from north to south but run from east to west. The belt dominated by Gray-Brown Podzolic soils is bordered on the north by Podzols and Brown Podzolic soils. The profile of one of the Podzols in New England, Brassua sandy loam, has been described earlier and is illustrated in Figure 3. The word "podzol" comes from a Russian

folk name for ashes which is what the peasants thought of the white or light gray horizon immediately beneath the surface mat of organic matter. Podzols are the dominant soils in the broad Taiga belt across northern Europe and Siberia. Brown Podzolic soils, important in much of New England, are closely related to Podzols but commonly have a thinner surface layer of organic matter and lack a distinct light gray or white underlying horizon. When these soils are cleared and plowed, the upper horizons are mixed and the soils are hard to tell apart. Podzols are most often formed under pines or other cone-bearing trees. As the needles fall and decay, they become very acid and the water passing through them becomes acid in turn. These acids seem to attack many minerals vigorously, after which percolating waters carry dissolved materials out of the soil. The light gray or white horizon immediately below the organic mat has been bleached by the removal of iron oxides from this to the next underlying horizon. Because of the strong leaching the soils are very acid and low in most plant nutrients. You all know the story of how the early colonists in New England learned from the Indians to put a fish into each hill of corn. The Indians were using the only fertilizer they knew.

The Podzols and Brown Podzolic soils are in a region with much shorter growing seasons than the Great Soil


GENERAL PATTERN OF GREAT SOIL GROUPS
ZONAL
Great groups of soils with well-developed soil characteristics, reflecting the dominating influence of climate and vegetation. (As shown on the map, many small areas of intrazonal and azonal soils are included.)
PODZOL SOILS
Light-colored leached soils of cool, humid forested regions.
BROWN PODZOLIC SOILS
Brown leached soils of cool-temperate, humid forested regions.
GRAY-BROWN PODZOLIC SOILS
Grayish-brown leached soils of temperate, humid forested regions.
RED AND YELLOW PODZOLIC SOILS
Red or yellow leached soils of warm-temperate, humid forested regions.
PRAIRIE SOILS
Very dark brown soils of cool and temperate, relatively humid grasslands.
REDDISH PRAIRIE SOILS
Dark reddish-brown soils of warm-temperate, relatively humid grasslands.
CHERNOZEM SOILS
Dark-brown to nearly black soils of cool and temperate, subhumid grasslands.
CHESTNUT SOILS
Dark-brown soils of cool and temperate, subhumid to semiarid grasslands.
REDDISH CHESTNUT SOILS
Dark reddish-brown soils of warm-temperate, semiarid regions under mixed shrub and grass vegetation.
BROWN SOILS
Brown soils of cool and temperate, semiarid grasslands.
REDDISH BROWN SOILS
Reddish-brown soils of warm-temperate to hot, semiarid to arid regions, under mixed shrub and grass vegetation.
NONCALCIC BROWN SOILS
Brown or light reddish-brown soils of warm-temperate, wet-dry, semiarid regions, under mixed forest, shrub, and grass vegetation.
SIEROZEM OR GRAY DESERT SOILS
Gray soils of cool to temperate, arid regions, under shrub and grass vegetation.
RED DESERT SOILS
Light reddish-brown soils of warm-temperate to hot, arid regions, under shrub vegetation.
INTRAZONAL
Great groups of soils with more or less well-developed soil characteristics reflecting the dominating influence of some local factor of relief, parent material, or age over the normal effect of climate and vegetation. (Many areas of these soils are included with zonal groups on the map.)
PLANOSOLS
Soils with strongly leached surface horizons over claypans on nearly flat land in cool to warm, humid to subhumid regions, under grass or forest vegetation.
RENDZINA SOILS
Dark grayish-brown to black soils developed from soft limy materials in cool to warm, humid to subhumid regions, mostly under grass vegetation.
SOLONCHAK (1) AND SOLONETZ (2) SOILS
(1) Light-colored soils with high concentration of soluble salts, in subhumid to arid regions, under salt-loving plants.
(2) Dark-colored soils with hard prismatic subsoils, usually strongly alkaline, in subhumid or semiarid regions under grass or shrub vegetation.
WIESENBÖDEN (1), GROUND WATER PODZOL (2), AND HALF-BOG SOILS (3)
(1) Dark-brown to black soils developed with poor drainage under grasses in humid and subhumid regions.
(2) Gray sandy soils with brown cemented sandy subsoils developed under forests from nearly level imperfectly drained sand in humid regions.
(3) Poorly drained, shallow, dark peaty or mucky soils underlain by gray mineral soil, in humid regions, under swamp-forests.
BOG SOILS
Poorly drained dark peat or muck soils underlain by peat, mostly in humid regions, under swamp or marsh types of vegetation.
The areas of each great soil group shown on the map include areas of other groups too small to be shown separately. Especially are there small areas of the azonal and intrazonal groups included in the areas of zonal groups.
AZONAL
Soils without well-developed soil characteristics. (Many areas of these soils are included with other groups on the map.)
LITHOSOLS AND SHALLOW SOILS
(ARID-SUBHUMID)
(HUMID)
Shallow soils consisting largely of an imperfectly weathered mass of rock fragments, largely but not exclusively on steep slopes.
SANDS (DRY)
Very sandy soils.
ALLUVIAL SOILS
Soils developing from recently deposited alluvium that have had little or no modification by processes of soil formation.

After map, *Soil Association of the United States*, Published in *Soils and Men*, Yearbook of Agriculture for 1938. Division of Soil Survey, Bureau of Plant Industry, U.S.D.A.

Figure 4—Map showing general patterns of Great Soil Groups in the United States.

Groups further south. Because of this, short season crops such as small grains, potatoes and hay are grown widely. As they have been used for crops over the years, the soils have been limed and fertilized a number of times. Soils that have been cultivated are therefore at higher levels of fertility now than they were under natural conditions. Furthermore, erosion is seldom a problem with the Podzols and Brown Podzolic soils. By and large, the soils have been improved by the shift from a natural to a cultural environment

Red-Yellow Podzolic Soils—If we shift our direction of travel again and go south, this time across the zone dominated by Gray-Brown Podzolic soils, we shall come to soils which are much brighter in color and also a great deal deeper than any that we have seen before. The deeper horizons of soils in the southeastern United States are commonly red or yellow in color and some are very bright indeed. The prominence of these bright colors is in sharp contrast to the appearance of soils in other parts of the country. These soils with bright colors are the Red-Yellow Podzolic soils, formed in a relatively warm and humid climate under forest.

In undisturbed areas, the Red-Yellow Podzolic soils have a dark surface horizon usually less than an inch deep over a pale yellow, often sandy, horizon that is a foot or more thick. This rests in turn upon a red or yellow horizon of considerable thickness that is higher in clay, often hard when dry, and sticky when wet. The red or yellow colors in these soils, like the brown colors in the deeper horizons of the Podzols, are due to iron oxides. These soils are strongly weathered. Large quantities of water have percolated through these soils and left only small amounts of soluble plant nutrients. Some of the soils contain mere traces of calcium and potassium. In a greenhouse experiment barley seedlings growing on the upper horizons of one Red-Yellow Podzolic soil died for lack of calcium except in pots that had been limed.

As a rule, Red-Yellow Podzolic soils are so low in plant nutrients under natural conditions that they cannot be cultivated steadily without the use of fertilizers. The early colonists along the southern half of the Eastern Seaboard had to clear new areas regularly as the first few crops grown used the small supplies of plant nutrients. The new land, like the old, was extremely low in plant nutrients. The practice of shifting culture is still followed on Red-Yellow Podzolic soils in those parts of the world where modern technology does not provide fertilizers. Without commercial fertilizers to improve and maintain the Red-Yellow Podzolic soils, no permanent agriculture is possible. We might add that the soil is rarely damaged by the practice of shifting culture. Once an area is abandoned, it is soon covered again by natural vegetation after which the slow process of concentrating a small supply of plant nutrients in the surface horizons is started again by the forest.

When commercial fertilizers became available, shifting cultivation ended and steady cultivation of Red-Yellow Podzolic soils began. With this change in use of the soils, considerable erosion occurred as fields were left bare during the rainy winter season. This erosion was especially harmful where it took the form of gullying. Such areas are no longer suitable for crop production although they can support trees. If erosion simply removed part of the light colored upper horizon, however, it had little permanent effect on productivity. Actually, many of the Red-Yellow Podzolic soils are more productive if part of the underlying red or yellow horizons can be mixed with the surface soil.

A first step in the effective control of erosion of Red-Yellow Podzolic soils is the improvement of fertility levels. Improvement is necessary before the soils will support vigorous plant cover. Without such vegetative cover, terraces concentrate the water and thus start gullies on the hillsides.

It is not possible now to determine with any accuracy the effect of past erosion on the productivity of the Red-Yellow Podzolic group. Some have been damaged through erosion, and others are more productive now than they were in their natural environment. It is true, however, that much larger acreages of the soils could be used with the knowledge available through modern science. Furthermore, the group as a whole could be far more productive than it is at the present time. The possibilities for increased production of food and fiber within the present cultural environment are greater on the Red-Yellow Podzolic soils than on any other group in this country.

Reddish-Brown Latosols—Moving further south, this time out of the United States and into warm and humid tropical regions, we find some of the reddest soils known. The brightest colored soils are the well drained ones formed from basic rocks of various kinds. These soils, called lateritic soils in the past and now known as Reddish-Brown Latosols, have reddish brown surface horizons, about 12 inches thick, grading into red to dark red underlying horizons, usually many feet deep. Like the Red-Yellow Podzolic soils, the Reddish-Brown Latosols are strongly weathered and deeply leached. Though commonly very high in clay, the soils are seldom sticky and plastic. This is due to the nature of the clay minerals and to the high contents of iron and aluminum oxides. In fact, some Latosols are mined as iron or aluminum ores. The Reddish-Brown Latosols generally have good physical properties but are low in soluble

plant nutrients. In the natural environment, a large share of the available plant nutrients is tied up in the growing vegetation and in the organic remains on and in the soil.

The Reddish-Brown Latosols are moderately productive when first cleared, even if used without benefit of modern technology and its products. With their favorable physical properties and the supplies of plant nutrients released by decay of the natural vegetation, the soils will produce several fairly good crops. The soluble nutrients are soon gone, however, and shifting cultivation is therefore common practice on the Reddish-Brown Latosols where commercial fertilizers and the like are not available. In the Palau Isands, for example, a small patch is cleared and used for a single crop of casava, sweet potatoes, or taro, after which the patch goes back to grass or trees. Some years later, the same patch may be cleared and cultivated again. At any one time, however, the proportion of the soil in cultivation is very small indeed.

Shifting cultivation of the Reddish-Brown Latosols seems to have damaged very few of them. Amounts of plant nutrients removed by crops cannot be large, and similar amounts are again concentrated in the soil by natural vegetation once the soils are abondoned. Furthermore, the soils are extremely resistant to erosion as compared to other soils we know. The straight walls of terraces apparently cut in the soil prior to discovery of the Palau Islands by white men still stand without failure in Reddish-Brown Latosols. Changes from the natural environment under a shifting culture of the Reddish-Brown Lateritic soils are small, and there is little gain or loss in productivity. The soils remain essentially as they were prior to tillage.

If the change from the natural to a cultural environment includes the application of knowledge available through modern science, the Reddish-Brown Latosols can become productive indeed. A dramatic illustration of this can be drawn from comparisons of the agricultures in Hawaii and the Palau Islands, where the soils are essentially the same. The fields of sugar cane and pineapple produced with modern methods in Hawaii are in striking contrast to the little gardens tilled by hand in the Palau Islands. Large quantities of phosphorous fertilizers, as well as smaller quantities of lime and other fertilizers, are commonly used in Hawaii. Increased contents of phosphorus, for example, are measurable in the soils of a number of fields. Fertility levels of the Reddish-Brown Latosols are thus improved in a cultural environment that uses modern science. At the same time, there are unsolved problems in maintaining the favorable physical condition of the soils with the use of heavy equipment and the common cultural practices. Taking the picture as a whole, the productivity of the Reddish-Brown Latosols seems to be higher now than it was in the natural environment.

Shifting from Natural to Cultural Environments

To illustrate changes in the productivity of soils, a few of the great soil groups have been described together with comments on the shifts that follow their use by man. **As soils are used, the environment is changed, with but few exceptions. The forest or prairie is removed or destroyed and crops are grown. Water is added through irrigation or removed by drainage. In extreme cases, the whole soil is re-arranged, as is done on terraced hillsides on Okinawa or in some of the rice paddies in Japan. Commonly, the change in the environment is reflected, sometimes slowly and sometimes quickly, in the soils. Generally speaking, soils tend to become different in their natural environments. Under the cultural environment that we impose, the differences among soils and soil groups are reduced. We tend to lower fertility levels in the richest soils and to raise them in the poorest soils. Organic matter contents are lowered in some soils and raised in others. On the whole, we make more changes in chemical properties than in physical properties.**

Looking broadly at the changes in soils following their shift to a cultural environment, we should be hard pressed to prove that the net results had been either good or bad. Some of them have been bad beyond question; certain soils have been eroded to a point where they are no longer useful for crop production. Beyond that, other soils have been damaged to some extent. Deterioration of the soils in some cases, as for example the depletion of fertility in Chernozems and Prairie soils, has been beneficial to mankind. On the other side of the ledger, we can point to large areas of soils that have been improved in their new environments. The improvement of soils, such as the Red-Yellow Podzolic, Brown Podzolic, and Podzol groups has been essential to their effective use. These soils must be made more fertile than they are in the natural environment if stable economies are to be established on them. As we examine our use of soils in the past, we can say that we could have used many of them better, both for our immediate purposes and for the future, had we known more about them. At the same time, our knowledge and methods are continually improving. Someone looking back upon our handling of our soils from a vantage point in the distant future may well find that our stewardship on the whole was good.

Terrace Drainage of Almena Soils in Central Wisconsin

A. J. WOJTA, C. B. TANNER, AND R. J. MUCKENHIRN

The authors of this informative paper point out how a drainage system including channel type terracing and land leveling program was established on very poorly drained to moderately well drained land in central Wisconsin. The system, costing approximately $7.00 to $17.00 per acre, proved beneficial to corn, small grains and forage. Previous attempts to drain such soils included tile, bedding, large interceptor ditches, and ridge type terraces; all of which failed to provide adequate drainage.

THE ALMENA SILT LOAM soils and other poorly drained soils in the Spencer Catena comprise 4300 square miles in central Wisconsin.

Cultivated fields in this area range in slope from practically flat to 4 per cent. Wet soils at the lower portions of the long slopes and in many shallow field depressions (basins), delay spring seedlings, mire machinery, reduce crop yields, drown out seedlings, and hinder the harvesting of crops during wet fall seasons.

As indicated by Table I, internal drainage is poor from the plow sole downward. Root penetration below 24 inches is not significant unless special cultivation and fertility practices are followed. The soils have a fair available water range (F.C.—W.P.) but so little profile depth is filled with plant roots that short dry spells may easily produce wilting.

Table I. Physical Properties of Cultivated Almena Silt Loam[1]

Depth	Color	Sand	Silt	Clay	Upper Pl. Limit	Lower Pl. Limit	Field Capacity	Wilting Percentage
Inches		%	%	%	% (O.D.)	% (O.D.)	% (O.D.)	% (O.D.)
0–6	Dark gray	10	75	15	42	32	28	11
6–10	Pale brown mottled with yellow brown	15	75	10	26	16	21	7
10–30 or 36	Yellowish brown mottled yellow and light gray	19	65	16	22	20	21	7
30+ or 36+	Reddish brown compact	58	27	15	27	16	17	8

[1]Data obtained by R. J. Hanks in partial fulfillment of the M.S. required.

The extent of internal drainage in the Almena silt loam has not been thoroughly investigated but from information available to date, cannot be regarded as significant. The duration of water storage in surface basins is the first evidence of restricted water movement downward or laterally through the soil. Water may be stored in shallow (four to six inch) depressions for several weeks in the spring. Tile drains have never proved effective in this soil, thus further indicating the poor internal drainage of the soil. Tensiometer data for one year have indicated poor internal drainge. There is a belief by some workers that water movement at the plow sole may be appreciable in early spring when the plow layer is thawed and the lower depths are frozen. Saturated permeabilities for the various horizons of this soil have not been determined, but a program is underway to make these measurements and also, to estimate the movement of water at the plow sole. These data will improve the estimate of internal drainage; but from the above practical considerations, internal drainage cannot at present be regarded as substantial. The only significant drainage of the Almena is through surface run-off and this is usually poor because of irregularly sloping land and because of surface basins.

Past attempts to improve surface drainage have been limited to "bedding" and to cutting channels for drainage ways. Both of these procedures are unsatisfactory. Bedding has been practiced for many years. The extra large dead furrows spaced 20 to 30 feet apart, formed by successive plowings and located in a rectangular pattern, do not drain the surface water from the entire field. Moreover the corrugated ground surface is difficult to farm with tractor machinery.

Where ridge-type terraces have been constructed for erosion control, drainage is somewhat improved. However, the surface basins existing between terraces still provide water storage and thus terraces alone fail to provide adequate surface drainage. Further, ridge type

The studies covered in this paper were conducted under a current cooperative project including Soils, Agricultural Engineering, and Agronomy Departments, College of Agriculture, University of Wisconsin, and the Soil Conservation Service.

A. J. Wojta is Assistant Professor of Agriculture Engineering; C. B. Tanner, Instructor in Soils; E. J. Muckenhirn, Professor of Soils and Assistant Director of the Wisconsin Experiment Station.

The authors wish to acknowledge the assistance given them by personnel of the Soil Conservation Service (Research and Operation Divisions), particularly to Mr. H. B. Atkinson, Hydraulic Engineer, and A. Berkman, Farm Planner.

terraces are not readily crossed with harvesting machinery such as combines, field balers, etc.

Development of the Terrace Drainage System

The drainage channel type terrace system was developed to extend the effectiveness of terraces as surface drainage systems to the irregular surfaced, flat to gently rolling land up to 4 per cent slopes; and to provide a terrace system easily maintained and readily farmed with tillage, planting or harvesting equipment including field choppers, field balers, and combines. The drainage terrace system augments the natural undeveloped surface drainage pattern of the land by (1) reducing the overland flow of runoff, (2) the eliminating of standing water in the field, (3) the smoothing or "leveling" of the field surface.

Design Features: These systems are similar to the conventional terrace system, but in addition, the waterways and terraces serve as borrow pits for the earth needed to fill the field depressions. The waterways are constructed as vee or flat bottom shaped ditches without raised side banks, with a ratio of top width to depth of 20 to 1. A waterway 20 feet wide at the top would not be over a foot in depth. They are located in the natural drainage ways. Additional waterways may be provided to straighten or limit the length of the terraces.

The terraces are eavestroughs located across the slope to intercept the runoff, and also provide the earth needed to fill the field depressions located between the terraces. Cuts and fills limited to one foot in depth are frequently made to locate the terraces as straight and parallel as practicable. Terrace gradients of 0.5 per cent are desirable. However, terraces constructed to a 0.1 per cent grade for lengths up to 1,000 feet have been found effective, especially on the flatter slopes. It may be necessary to "create" a grade by deepening the lower reaches of the terrace.

Our studies have shown that terraces spaced between 125-150 feet apart, as measured on the ground surface are desirable. This spacing provides enough earth to drain the runoff into the terrace channel on the flatter slopes, and also is sufficient to protect 4 per cent slopes from erosion.

Construction: The construction of drainage terrace systems includes three earth moving operations: (1) earth hauling to eliminate field depressions and construct channel capacity, (2) earth rolling to create additional terrace capacity, (3) land smoothing or "levelling" the field surface between the terraces to prevent impounding runoff. Our field studies show that on both irregular surfaced and flat fields, from 30 to 90 cubic yards of earth was moved for each acre improved, in addition to the earth excavated from the waterway into which the terraces drain.

Two classes of earth moving machinery were used to improve 250 acres. These units included tractor scraper units (eight cubic yard capacity) and combinations of farm tractor-drawn scrapers, plows, and land levellers.

Contractor-Size Tractor Scraper Units: The tractor-scraper units were operated as single units to develop the complete system exclusive of the land smoothing operations. A summary of our findings based upon three different units, operated for a total of 100 hours are:

(1) The production capacity of the units was about 100 cubic yards an hour at a cost of 9½c per cubic yard in 1946.

(2) "Good footing" and optimum soil moisture conditions are conducive to maximum production.

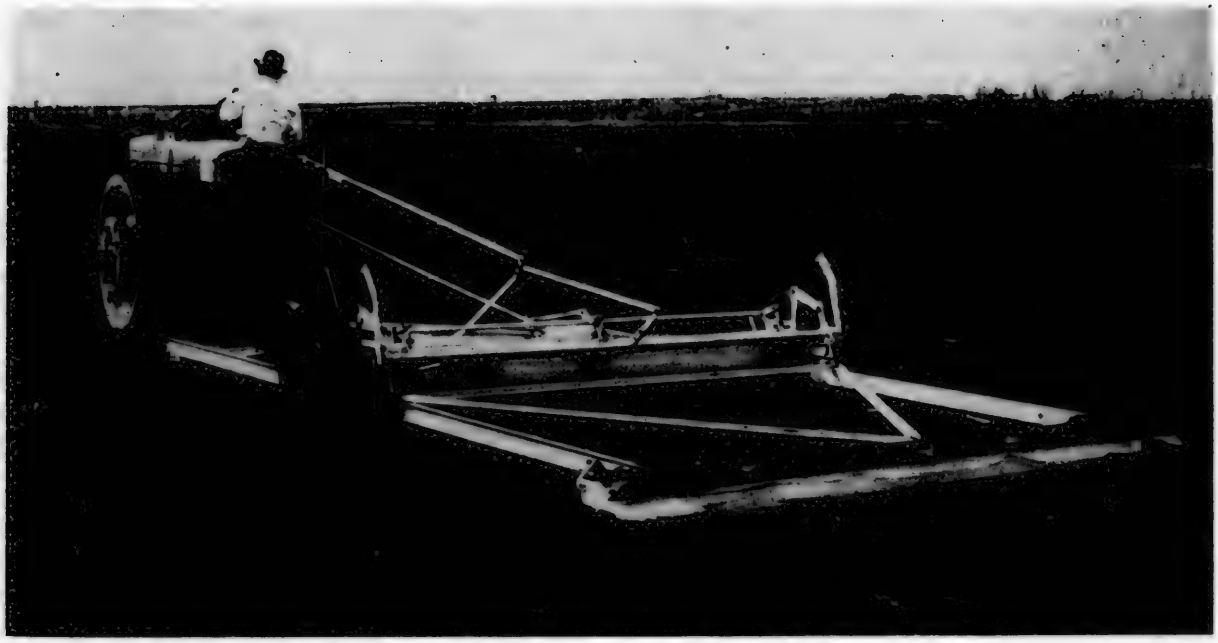
(3) Flat bottom shaped terraces with level bottoms located on sloping land are more difficult to build than vee shapes as the tilt of the cutting blade depends upon the tilt of the rear scraper wheels. The maintenance of the tilt of the machine and the resulting slope depends upon a full width of cut.

(4) The total average cost of improving one acre, including outlet cost of $1.75 was $17.00. The unit was rented for $10.00 per hour. Moving costs are included in the above costs.

Farm Tractor Drawn Scrapers: The scraper units were used as single units on the flatter and more irregular slopes to establish the terrace system. Adequate and uniform channel capacities of six to eight square feet were constructed and the earth from the terrace channel was used to fill the surface basins. On the more regular slopes, the scraper unit established the terrace grade performed the alignment (straightening out), and built the "uphill" side slope of the terrace channel.

Two types of hydraulically controlled farm tractor scraper units were studied, both powered by two or three plow tractors. A double stylus Servis Recorder located on the scrapers recorded the number of scraper dumps and the actual moving time of the unit. The instruments were calibrated by comparing their record of dumps and the average weight per load to the earth actually excavated.

A wheel type scraper (Soil Mover) with an average capacity of 0.85 cubic yards was studied. The width of the cutting blade was 42 inches. The scraper wheels were located behind and within the cutting width of the blade. The cutting, hauling, and dumping position of the bucket was actuated by two double acting cylinders powered by a pump and valve assembly mounted at the rear of the tractor and driven by the power-take-off shaft. Suitable mounting brackets made it possible to convert the unit to any two or three plow tractors. A control lever was located in easy reach of the operator. Our studies clearly indicated that three and two plow



A farm-size land smoother and scraper unit with automatic smoothing feature.

tractors, with experienced operators, were able to load the scraper without stopping, in 2nd or 3rd tratcor speeds. The unit operated by twenty different farm operators averaged 37 cubic yards of earth for each hour of moving time, or 1½ to 2½ scraper hours were required for each acre improved.

The production of a rear mounted scraper with a capacity of one-half cubic yard capacity was about 20 cubic yards of earth per hour (moving time). It appears that with either mounted or wheel scrapers the production of the scraper is proportional to the capacity of the bucket.

Farm Tractor Drawn Earth Rolling Equipment: When the earth needed to fill the basins in the field did not result in sufficient channel capacities, scrapers were used to form a low 2-3 inches high, 10-15 feet wide terrace ridge. Not only was the operation of the tractor and scraper tiring but the production was low when compared to rolling equipment. Therefore, the ordinary farm plow and whirlwind terracer plow were used in combination with the scraper. The terrace ridge or embankment was constructed from the upper side. The creation of a secondary channel which is improperly drained, and located between the back slope of the ridge and ground line, not only retains the runoff, but creates a formidable obstacle to the travel of farm machinery.

Field studies clearly show the advantages of a two-way plow over the whirlwind terracers when used to build a ridge in combination with the scraper as the idle travel of the two-way plow is considerably less than one-way equipment. The whirlwind plow does have advantages over the two-way plow in that the machine will perform equally well under extremely dry, or optimum soil conditions. The exception is rocky ground. The whirlwind plow is able to complete the construction of the ridge while construction of the ridge with plows may be delayed until the earth in the ridge has settled. Ordinary one-way plows, of course, are able to construct the wide low ridge. All of the plows, however, including the whirlwind have definite tendencies to form a narrow high ridge.

Farm Size Land Leveling Equipment: An Eversman Land Leveler Model 9PL and the John Deere Killefer land leveler powered by three plow tractors were used to smooth the entire field surface. Our observations and current studies indicate that land smoothing contributes more to surface drainage than terraces excepting in the lower reach of field slopes 500 feet or more in length. Smoothing operations are performed during the fall season.

Although these machines were used with scrapers and plows to establish terrace systems, they are combination machines that can be employed to construct the complete system including waterways. These units when used as drag scrapers (six to seven feet wide blades) were very effective in moving loose earth a short distance. The compaction of earth resulting from the earth pushed ahead of the blade, however, makes it necessary to continually loosen the surface soil.

A desirable method for constructing terraces with this

type of equipment consists of smoothing or leveling the entire field surface after the sod has been established in the waterway and then building the terraces with rolling equipment such as plows, etc. This equipment in combination with plows is well adapted to the flatter slopes with uneven ground surfaces.

The Eversman Land Leveler incorporating the automatic leveling feature provided a smooth even surface with the minimum use of the controls. Field data showed that from one to two hours of leveler time was needed to improve an acre after the scraper and plowing operations.

The John Deere Killefer land shaper (not designed as a finishing land leveling implement) was effective in creating a smooth even surface providing the operator was skillful in controlling the blade.

A relatively inexpensive land smoothing piece of equipment is the Diamondrag. A relatively good job of smoothing can be done with it providing the proper weight (stones) and speed are used.

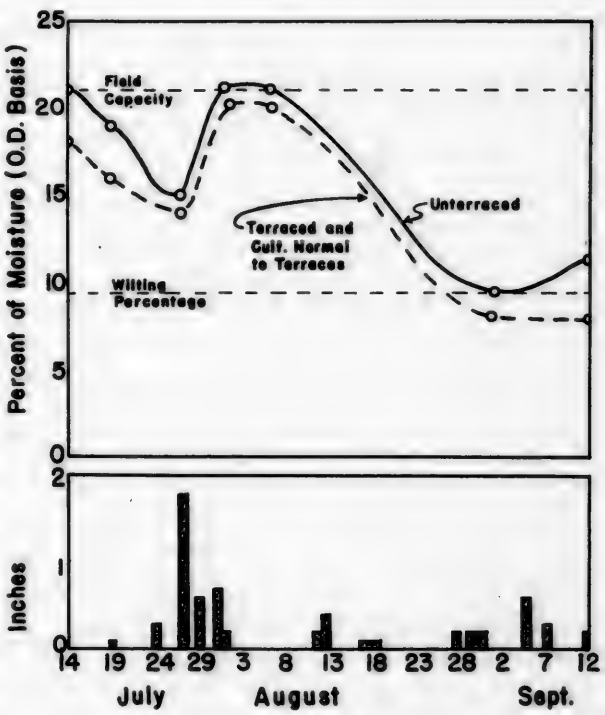
Soil-Moisture-Crop Relations Under Terrace Drainage

Water is removed from a soil through internal drainage, surface drainage, transpiration, and evaporation. In the Almena silt loam internal drainage is insignificant; whereas surface drainage provides for practically all of immediate drainage, particularly where land is either leveled or terraced and leveled. The loss of water by evaporation is not significantly different on drained and undrained land in the early spring. Further, it is not an important factor as compared to surface drainage in removing water from improved land. Removal of water by growing plants is appreciable after plant growth begins. Since the drainage system used allows forage and grain crops to be established on land that cannot otherwise normally be planted to crops, a considerable drainage benefit is derived. For example, when the land has been planted to a forage crop, considerable water is utilized either in the early spring or during a wet fall and the soil can be tilled earlier in preparation for some crop in the rotation. On untreated land, crop growth (when crops can be established) is sparse and irregular, with frequent patches of winter killed plants. This soil will dry to a suitable tillage state irregularly and slowly.

Poorly Drained Land: Present evidence indicates that desirable forage crops and grains can be grown and maintained on land with very poor natural drainage after a drainage system has been constructed. Without the drainage improvements crops can be established only with difficulty or not at all. After establishment crops will not persist on undrained land but lack uniformity suitable density and will frequently winter kill. The drainage of poorly drained land allows tillage equipment to operate early in the spring, thus preparing a seed bed on land which otherwise would be tilled much later in the year and which in wet years could not be tilled at all. In 1948 a portion of a field at the Marshfield Branch Experiment Station, Wisconsin, was terraced. The part terraced had not been planted to crops in previous years because of the unusually wet field conditions extending on occasion into July. The part left unterraced was the highest, most sloping ground in the field. In 1949, even the lowest reaches of the terraced field were sufficiently dry to work two weeks prior to the better, unterraced land. Thus the results of terracing very poorly drained land growth permit the use of otherwise unusable land.

Moderately Well Drained Land: There is some land with greater slopes that can be cropped without drainage improvements but may be improved by a drainage system. The crop moisture relations on this land were particularly studied since moisture relations on better land would determine the advisability of terracing. At the Marshfield Branch Experiment Station, Marshfield, Wisconsin, soil moisture was measured under corn grown on the *better land* (*with few or no surface basins*) with and without improved surface drainage. The measurements for 1949 were made to depths of two feet.

Figure 1. Average Soil Moisture Content in Corn Root Zone (1949).



Where no surface drainage was employed, little water was taken at and below two feet. On the terraced land (cultivated normal to terraces) considerable water was used at two feet and some use at three feet was indicated. A general summary of the moisture results for 1949 is given in Figure 1. In 1949 the rainfall was considerably below normal during the corn season. That year, the corn on the terraced land (cultivated normal to terraces) showed incipient wilt five days before that on unimproved land. Permanent wilting occurred on terraced land (cultivated normal to terraces) five days following incipient wilting, but did not occur on the unterraced land. On terraced land cultivated parallel to the terraces no wilting occurred. Yields on the land terraced and cultivated normal to terraces, terraced and cultivated parallel to terraces, and unterraced were respectively 54.1, 75.1, and 65.7 bushels per acre. Improvement was greatest where terraced for drainage, but cultivated parallel to terrace for optimum water storage during the drier part of the season.

The weather during the season of 1950 was more nearly average than in the extremely dry year of 1949. The spring of 1950 was cold and wet and planting was delayed somewhat past the usual planting date. From July 25 to August 25 there was little precipitation but no crops lacked water because of low temperature and high humidity. In fact there was little drying of the soil below the one foot depth. In Figure 2 the general moisture trends are shown under terraced land with cultivation both parallel to the terraces and normal to the terraces. Moisture trends are also given for unterraced land. The one unexpected result was that least water was found in the soil where cultivation was parallel to the terraces. The explanation advanced may be that the soil was very wet for both cases of cultivation, and humid conditions prevailed. Where the corn was drilled parallel to the terrace, the rows were in a North-South direction; thus increased solar radiation down the rows and prevailing winds from the South-West induced better conditions for transpiration and evaporation.

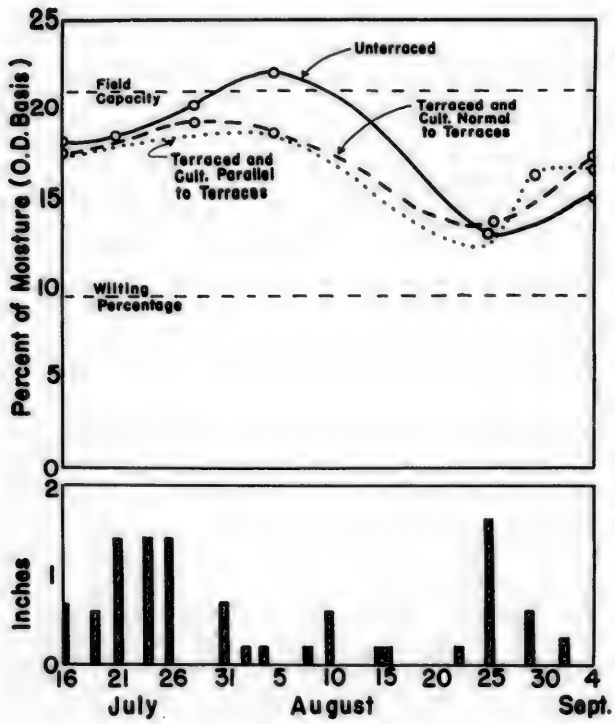
Corn did not mature to shelling stage in 1950 but was harvested as silage. The yields on the lands terraced and cultivated normal to terraces, terraced and cultivated parallel to terraces, and unterraced were respectively 11.2, 16.6, and 10.3 tons fresh weight per acre. Terracing was found advantageous. Since water was at no time limiting, the terraces gave rise to no adverse effects on moisture.

Results for 1949 and 1950 indicate that terracing is worthwhile in wet years. In dry years, terracing may provide excessive runoff with consequent reduction in yield. In those years where the soil does not remain wet (near field capacity), cultivation parallel to the terraces provides additional storage of precipitation in the growing season. This offsets the disadvantages of the terraces in assisting the runoff of desirable water and thus is advisable.

Extended Trails: In 1949, six fields widely located in Central Wisconsin and previously selected to represent different conditions of internal and surface drainage, were planted with oats and seeded with grass legume mixtures. The field sizes varied from four to ten acres. Three fertility levels were established (none, 500 lbs., and 1500 lbs. of 0-12-36 per acre). Lime was applied uniformly on each of the six fields as needed. No soil moisture information was obtained on the six fields, but the yield differences and field observations were significant. The unterraced section of each of the trial fields was situated in that part of the field with best drainage properties. With this disadvantage of field position, 1949 tests showed that the terraced fields yielded slightly more oats than the unterraced fields. On terraced fields, the yield at the lower part of the slope was substantially the same as the yield at the upper part. Normally, on the unterraced land, yields on the upper part of the slope are greater. The only place where oat yields were considerably lower (about one-half) on terraced land was in the channel where top soil was removed. One

(*Continued on page* 98)

Figure 2. Average Soil Moisture Content in Corn Root Zone (1950).



The Wrong Turn

FIRMAN E. BEAR

IN A RECENT BOOK on *"The Recovery of Culture,"*[1] Henry Bailey Stevens makes some highly interesting comments on the primate family, which includes monkeys and other forerunners of man and came into existence some 60 million years ago. He then analyzes some important happenings during the age of man, who has been on the scene only about 1 million years. *Stevens eventually comes to the conclusion that somewhere along the path of life man made a wrong turn. As a result, we now have wars, soil exhaustion, and impoverished and starving peoples in many parts of the earth. That wrong turn, he says, was the change from vegetarianism to the eating of meat.*

It is not my purpose to pursue this concept further. But meat-eating animals are much more savage than the grazing types. The rate of soil exhaustion is more rapid during wars, when heavier demands are made on the land than in periods of peace. Civilizations have fallen with continued wars and related impoverishment of the soil. Ruins of ancient cities are always found by digging away the soil that water, wind, and other agencies of the centuries have deposited on top of them.

A given area of land can be made to feed a great many more people if livestock are not interposed between crops and man. About six-sevenths of the calorific value of grain is lost by feeding it to livestock and then consuming the animals or their produce. The food-producing potentialities of the arable portions of the earth could be multiplied several times if we turned to a grain, nut, fruit, and vegetable diet and did away with the eating of meat.

Transforming City Refuse into Compost

I propose to deal with another wrong turn that man has taken, the results of which are referred to in a recent book on *"Soil Fertility and Sewage"*[2] by J. P. J. Van Vuren. He states that "erosion is a specific disease of the soil caused mainly by a humus-deficiency." This humus, he says, must either be manufactured in the soil itself from large amounts of crude organic material or it must be applied as manure or compost.

Van Vuren's concern is with the prodigality of the waste of fertility in cities where the produce of the farm is largely consumed. He has developed a method by which city refuse is rapidly transformed into compost. For each 10,000 people in the South African city where he is located, there are 250 cu. ft. dry refuse and 500 gallons night soil a day. To handle this he uses a trench system with a volume of 10,000 cu. ft. From this, 1,000 cu. yds. of sieved compost is produced at a total cost of about $1 a cu. yd. All the work is done by hand at very low labor cost.

Figure 1. Forty-five organic-matter systems being tested in 364 three-foot-deep cylinders of soil at the New Jersey Agricultural Experiment Station.

A modern solution of this problem is presented in the report of the Refuse Disposal Company, Ltd.[3] of Holland. An installation at Wyster handles 150,000 tons of town waste annually, most of it from The Hague. Trains carrying this refuse run on one of four viaducts that are 20 feet high and 1,000 feet long. When a train stops, the bottoms of the vans are opened automatically and the material drops into the pit on both sides. It is then mechanically leveled and sprinkled with water. Additional trainloads are added on succeeding days until the pile is 20 feet high.

After the material has been allowed to ferment from four to eight months,[4] with frequent mechanical turning, the resulting compost is dug out with a traveling crane. This places it in a bunker from which it is released into lorries attached to an endless cable that de-

Dr. Firman E. Bear presented this paper at the Annual Meeting of the Southern New England Chapter of the Soil Conservation Society of America, New Haven, Connecticut, October 20, 1950. Dr. Bear is a past-President of the Soil Conservation Society of America and is Chairman, Department of Soils, Rutgers University, New Brunswick, New Jersey.

[1] Harper and Brothers Publishers, New York, 1949.
[2] Dover Publications, Inc., New York, 1950.
[3] N. V. Vuilafvoer Maatschappij V.A.M.
[4] The longer period is required in the summer.

livers it to the factory. There it is unloaded by mechanical means, screened, magnetically freed of iron, and pulverized in a hammer mill. The finished product is free of glass spinters, has an earthy appearance, and is practically odorless. The factory is now operating at full capacity and produces 80 tons an hour.

The composted product contains[5] up to 0.5 per cent N, 0.5 per cent P_2O_5, 0.2 per cent K_2O, 3.0 per cent CaO, 0.3 per cent MgO, 0.005 per cent B, and 0.04 per cent Cu. In addition there are small amounts of all the other essential minor elements, nine per cent organic matter, and 30 per cent moisture. The material is high in mineral matter that, during the winter, comes largely from the ashes of house fuel. Applied at the rate of 20 to 40 tons an acre, it raises the pH value of the soil, supplies large amounts of the standard fertilizer elements, and overcomes deficiencies of boron and magnesium. It has a marked effect in improving the adsorptive capacity of sandy soils. The cost of production is said to be less than $1 a ton.

Holland finds it necessary, by reason of an unfavorable trade balance, to produce all of her own food. In doing this, use is made not only of the manure from 2½ million dairy cows but of more mineral fertilizer an acre than is applied in any other country. But additional organic and mineral matter is needed to attain the yield levels desired.

When one looks about the United States and sees the extent to which land is being put to the plow, the carelessness with which topsoil is allowed to be carried away by wind and water, and the rate at which fertilizer consumption, of necessity, is increasing, he cannot but wonder how long this can be continued with impunity. Large amounts of poultry and pig manure are never hauled to the field and much of the sewage sludge is gotten rid of by the most convenient means at hand. Some of it is burned, some is buried, and some is dumped into the ocean. And the same applies to virtually all of the city garbage, ashes, and other wastes.

Providing Organic-Matter Needs of Soils

It has been clearly demonstrated that sod-crop rotations and cover-crop programs, if systematically employed in conjunction with mineral fertilizers, can be made to meet most of the organic-matter needs of soils. But with each succeeding war, more land is put to the plow. Modern soil-working machinery operates with such efficiency that farmers get a great deal of pleasure out of using it. For a time, extra fertilizer can be made to compensate for excessive cultivation. As a result, the habit is established of keeping the land under more or less continuous cultivation to a single crop or to a restricted group of crops.

Grass-legume sod crops are of such fundamental importance in rebuilding the granular structure in cultivated soils, in supplying organic matter, in pushing this organic matter down deep into the subsoil, and in stopping erosion that we can ill afford not to make regular use of them. What can be done with the grass-legume program, however, and what is being done with it are two fundamentally different things. The fertilizer industry would do well to encourage studies along this line, especially of means by which higher acre yields of cultivated crops can be produced with less rather than more fertilizer.

Considerable areas of land have accumulated fertilizer phosphorus and potassium to the point where they no longer respond to the addition of these elements. But this does not apply to nitrogen. Under conditions of adequate supplies of the other nutrient elements, one seldom sees an upland soil that contains too much of this element. Usually, a nitrogen topdressing or sidedressing produces such marked growth and color effects as to be very readily seen, assuming that a check area is available for comparison. This means that the supply of organic matter, the storage agent for nitrogen, is inadequate. Other evidence of lack of organic matter is found in the increasing tendency toward minor-element deficiencies in cultivated soils that have been brought to a high level of productivity by heavy use of concentrated inorganic fertilizers.

Instead of looking with a jaundiced eye at the efforts of the organic-farming enthusiasts to develop organic-matter supplies for use on the soil, the fertilizer industry would do well to interest itself in this problem. There is need for study of the possibilities for recovery of city wastes. But the real opportunity lies in the development of long-range grass-legume sod and cover-crop programs.

For some ten years we have been carrying on an intensive study of soil organic-matter systems that might be applied to the production of truck crops. The crops grown were snap beans and carrots. The pH value of the soil was maintained between 6.0 and 6.5 and the equivalent of one ton 7-7-7 fertilizer an acre was applied each year. In addition, magnesium sulfate and borax were applied. Notwithstanding the liberal use of fertilizer, a 12 per cent higher yield was obtained by leaving the crop residues on the soil than by removing them. A rye cover crop added another 7½ per cent to the yield vetch in addition to rye three more per cent, and 2½ tons cornstalks a further 11½ per cent. For organic matter additions totaling a little over five tons dry

[5]Except for N, all the figures are in terms of water-soluble or "available" materials.

Figure 2. Farmers in some of the more intensive cropping areas in New Jersey feed steers primarily for the manure they produce.

matter an acre annually, the yield increase averaged 34 per cent on this very liberally fertilized soil.

In examining the crop refuse, sods, and cover crops that were incorporated into the soil in these experiments, attention was given to their content of minor elements. Comparative analyses were made of rye, ryegrass, vetch, and alfalfa and of snap bean and carrot wastes from the same soil. The rye was much lower in all the minor elements than the ryegrass. Vetch was exceptionally high in B, Co, Mo, and Zn. Alfalfa and carrot tops were very high in Mn and bean tops in B.

Weeds Add to Minor Elements in the Soil

These data point in the direction of the need not only for more organic matter but a variety of kinds of it, no matter whether we are thinking of a cover-crop system or one involving sod crops. Many weeds make highly important contributions in mobilizing minor elements in the soil. Ragweeds and lamb's quarter, for example, are excellent accumulators of zinc. It is conceivable that they might be deliberately grown for the purpose of mobilizing this element.

Sod and cover crops should be liberally fertilized with complete fertilizer. Nitrogen alone is not desirable, since this tends to develop top growth at the expense of roots. A complete fertilizer helps them develop not only larger tops but larger root systems as well that accumulate more mineral elements from the lower soil depths. When such sod and cover crops are worked into the soil, they provide excellent food for soil microbes, and these microbes liberate large amounts of all the essential mineral elements, including nitrogen, from them.

Certain types of crop residues and cover crops yield antibiotic-like substances that destroy bacterial and fungus parasites. The latest issue of Annual Review of Biochemistry[6] mentions allicin from onions, lupulon from hops, rhein from rhubarb, tomatin from tomatoes, and a number of others from a considerable variety of plants, including ragweeds and sweet potatoes. Something very important along this line can no doubt be accomplished by the right choice of sod and cover crops or by making adjustments in crop sequence in the rotation program.

The fertilizer industry represents the most important chemical development, in terms of human values, the world has ever known. Fertilizers can be made to stand between us and any possible deficiency of food for centuries to come. But fertilizers alone, no matter how heavy the rate of application, will not meet the requirements for soils that are producing cultivated crops. Soil must be fed organic matter in larger amounts than the roots and residues of such crops can provide. This requires manure and well-chosen mixtures of sod and cover crops. If, in addition, we can develop means of producing supplemental compost from city refuse, or by any other means, so much the better. In my opinion, we should lend assistance to efforts that are designed to avoid waste of organic materials. It might well pay to subsidize the processing of such organic wastes as can be made available for use on intensively cropped land.

---

[6]Annual Reviews, Inc., Stanford, California, 1950.
After map. *Soil Associations of the United States*, published in *Soils and Men*, Yearbook of Agriculture for 1938. Division of Soil Survey, Bureau of Plant Industry, U.S.D.A.

The Water Situation in the United States

JOSEPH V. B. WELLS AND ADRIAN H. WILLIAMS

During the past half century the use of water has increased more rapidly than our population. Although complete figures on the use of water are not available, it has been estimated on the basis of fragmentary data that municipal water use in the United States has increased six-fold during the period 1890 to 1945, while the population increased two-fold.

According to studies an average of 30 inches of water falls as rain, hail or snow each year, and that about 22 inches is evaporated or used by vegetation, and eight inches runs off into the ocean after traveling through the ground. This eight inches represents the bulk of the water available for use by man, and it is several times greater than the present use.

THIS SUBJECT IS BROAD indeed. It covers a very large area, in which nearly every conceivable condition pertaining directly or indirectly to adequacy of water supply may be found to exist. Only general statements concerning the water-supply situation would be widely applicable.

The immediate sources of our water supplies may be placed in two broad classifications—surface water and ground water. These two sources, which frequently are thought of as independent, actually are closely related. Percolation from surface streams and ponds is one source of ground water. On the other hand, ground-water effluence sustains stream flow after direct runoff has ceased. Part of this effluence may be former surface-water runoff that has taken a ground-water route to its point of reappearance as surface flow, whereas the remainder of the effluence comes from infiltrated precipitation or from deep-seated ground-water reservoirs that are capable of storing water over a period of years and releasing it at a reasonably uniform rate. It is this latter source that largely sustains stream flow during extended periods of droughts, and that, when depleted by long droughts or heavy pumping, adversely affects stream flow. It is estimated on the basis of incomplete data that approximately one-third of the surface water that runs off the country into the ocean or crosses our national boundaries has passed through ground-water channels or ground-water reservoirs before entering the larger streams. In a basin in which the ground-water divide follows the physiographic divide, which generally is true of a large basin, the surface outflow is the overflow—the residual of precipitation—after all withdrawals, including that which has gone into ground-water storage, have been made. Surface-water and ground-water bodies cannot both be considered as permanent sources of supply independent of each other. Withdrawals of water from a ground-water body may result in a diminution of flow in the surface stream or streams with which that ground-water body is associated. Hence, on a long-term basis, the surface outflow from a basin may be considered as a measure of the ultimate water resources of that basin. For that reason we are focusing these remarks mainly on our surface water resources.

This paper by Joseph V. B. Wells and Adrian H. Williams was presented at the Annual Meeting of the Soil Conservation Society of America held in Detroit, Michigan, October 26-28, 1950. Mr. Wells is Chief, Surface Water Branch, U. S. Geological Survey, Department of Interior, Washington, D. C. Mr. Williams is Assistant Chief of the Surface Water Branch.

No Apparent Downward Trend in Water Supply

First of all, we want to emphasize the fact that the water-supply situation is simply a matter of the relation between supply and demand. The situation becomes critical when demand in some spot or area or region exceeds supply. Supplies locally are frequently somewhat variable and unpredictable and must be considered in light of their geographical as well as quantitative availability; the demands of our civilization tend to be inelastic and are growing. In nature, plants and animals adjust themselves to the sustenance available. Naturalists have estimated that, prior to the coming of white man, the number of buffalo roaming the western plains of North America varied in number between a minimum of about 20 million and a maximum of about 60 million. During a sequence of good years—presumably years during which luxuriant range resulted from ample rainfall—the buffalo multiplied in numbers; during poor years, the buffalo decreased. We cannot expect human beings to continuously readjust their procreation and their culture in conformance with the vagaries of nature, but eventually they must be adjusted to a dependable supply of water.

We read and hear so much about the water supply

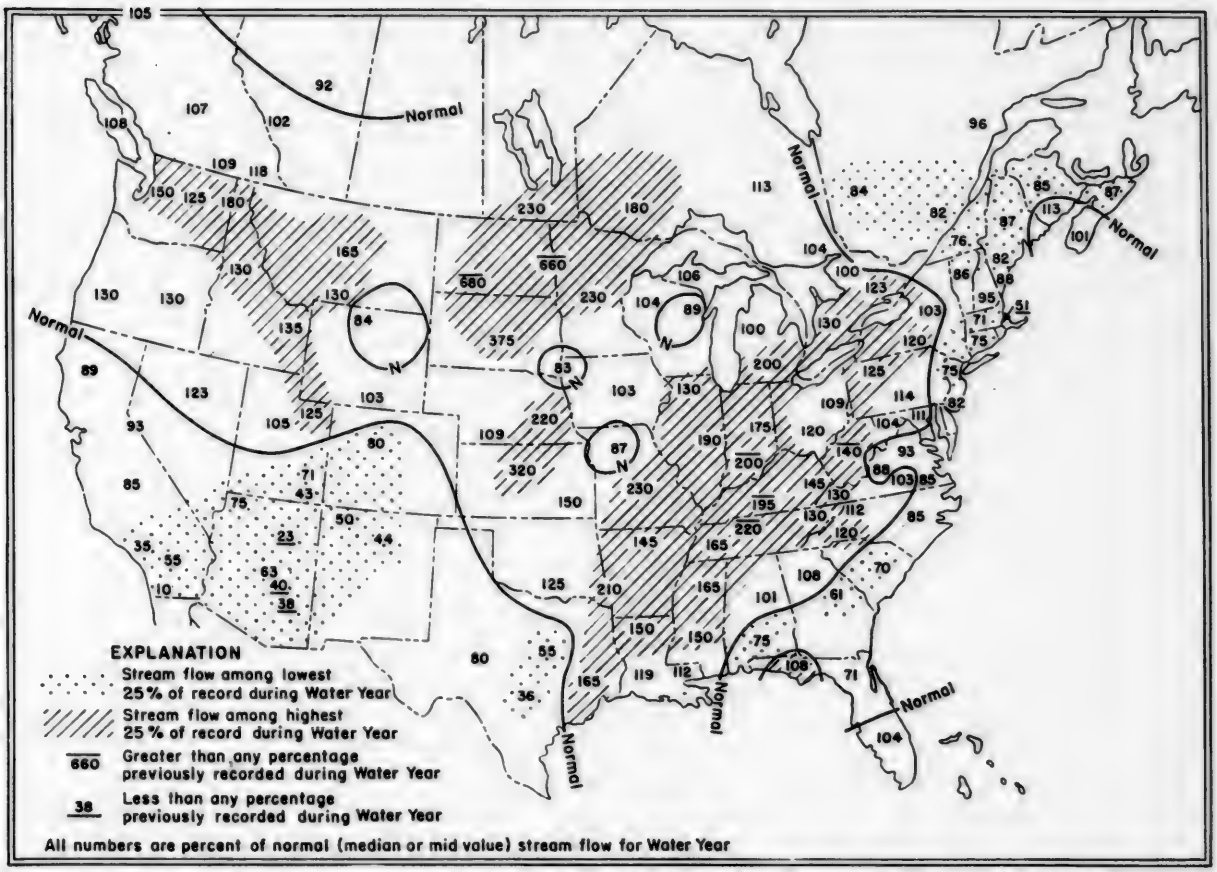

EXPLANATION
Stream flow among lowest 25% of record during Water Year
Stream flow among highest 25% of record during Water Year
660 Greater than any percentage previously recorded during Water Year
38 Less than any percentage previously recorded during Water Year
All numbers are percent of normal (median or mid value) stream flow for Water Year
Normal

Figure. 1. This map shows the percentage of normal stream flow water for the year ending September 30, 1950.

shortage in the United States that we might well be led to believe that it is not only becoming increasingly more grievous but that it may soon reach calamitous proportions. In some specific localities, that may be. However, despite the rather widely accepted belief that runoff and ground-water levels are declining, hydrologic data, including stream-flow, ground-water levels, and precipitation records, have so far failed to indicate any widespread downward trends.

The Geological Survey recently made a brief study to compare average yearly precipitation during the 25-year period 1921-45 with that during the 50-year period 1896-1945. For this study the country was divided roughly into six regions within which climatic conditions are reasonably similar. Representative precipitation records were used for each region for each of the two periods. For the northwestern and north-central regions, the ratio of the average yearly precipitation during the 25-year period to that during the 50-year period is slightly less than one, indicating a slight decrease in precipitation during the last 25 years. For the remaining four regions the ratio was slightly greater than one, indicating a slight increase in precipitation during the last 25 years.

Stream-flow records collected by the Geological Survey cover a shorter period than many precipitation records. The Geological Survey now operates more than 6,000 gaging stations in the United States, a number of which have been in continuous operation for 50 years or more. Generally speaking, no significant long-term change in runoff is indicated, when adjustment is made for increased consumptive use of water. We must realize, of course, that records going "as far back as the mind of man runneth not to the contrary" cover a period that is only a grain on the sands of time and that we are not yet in a position to make really long-time comparisons based upon continuous scientific records.

Studies Show Previous Dry Periods

Students of climatic trends, notably in the western United States, have resorted to indirect methods of obtaining information on precipitation and runoff prior to the systematic collection of hydrologic records.

Otis S. Freeman (1) studied stumps of dead trees on the banks of many lakes in Eastern Washington during

the summers of 1926 and 1927 when after ten years of deficient rainfall the level of the lakes was the lowest since settlement of the country by white men. The age of the trees at the time they were killed by the water indicated that at one time the lake had remained for more than a century at a level lower than the low levels of 1926 and 1927.

When Goose Lake in Oregon almost dried up in the summer of 1926 after several exceptionally dry years, wagon ruts were found in the dried-up portions of the lake bed. Inasmuch as the floor of the lake had never been exposed since the region was permanently settled, it is presumed that these ruts were made by some pioneer's wagon in the decade around 1840, and that a wetter period set in soon thereafter, as evidenced by the accumulation of water in the lake.

S. T. Harding (2) studied the runoff of California streams on the basis of changes in levels in Tahoe, Eagle, and Mono Lakes. The study was carried back about 100 years on the basis of information disclosed by trees and stumps around the margins of the lakes. He concluded from these studies that, in general, the runoff into these lakes during the 75 years prior to 1935 was greater than during any similar period in the preceding 200 to 300 years.

H. B. Lynch of the Metropolitan Water District of Southern California issued a report in 1931, "Rainfall and Stream Runoff in Southern California since 1769," based on hydrologic and historical records. He concluded in part that, "There have been no material changes in the mean climatic conditions of Southern California in the past 162 years."

It is estimated that an average of 30 inches of water falls as rain, hail, or snow in the United States each year and that about 22 inches is evaporated or used by vegetation and eight inches run off into the ocean after traveling over or through the ground. This eight inches represents the bulk of the water available for use by man, and it is several times greater than the present use. However, the fact that our present use is only a fraction of the potential supply does not mean that we can regard our water situation with complacency. The total supply is distributed most unevenly both in place and in time. The arid portions of the West, where the climate and soil are highly favorable for productive agriculture if water can be provided, do not have enough water and perhaps never will unless it can be obtained by artificial means or by transporting it long distances. An example of the latter is the 340 miles that water is brought from the Colorado River to the Los Angeles area. The Bureau of Reclamation also is engaged in a project under its United Western investigations that includes a study of the feasibility of bringing Columbia River water to California.

Some Shortages Due to Over-taxed Distribution Facilities

In the more humid parts of the country there is a surplus of water, but unfortunately much of the surplus serves no useful purpose because it occurs in the form of floods that often do great damage. Even the humid areas are subject to occasional severe droughts as experienced in parts of the East in the last two decades. Also, some of the surface water, although available, is nearly or entirely unusable because of pollution, and requires treatment before it can be used. Much of the readily and cheaply available supplies of water of good quality in and near the great centers of industry and irrigation agriculture are already developed; additional supplies will be progressively more costly to obtain.

During the past half century the use of water has increased much more rapidly than our population. Although complete figures on the use of water are not available, it has been estimated on the basis of fragmentary data that municipal water use in the United States has increased six-fold during the period 1890 to 1945, while the population of the country increased two-fold.

Within the last two years New York City faced a critical water shortage. That did not indicate that the City's water supplies were permanently dwindling; it meant that the City is outgrowing its present water system and that storage facilities are becoming inadequate for carry-over through severe droughts. Studies already had been made of the feasibility of utilizing the waters of Delaware River for the expansion of New York City's water system. In fact, construction has been under way several years for part of this expansion. This study concluded that the Delaware River, with storage facilities, would provide a water supply more than adequate for all of that City's estimated future needs. It was further concluded that the project also would be capable of providing for the future water requirements of northeastern New Jersey, the Southern New Jersey Metropolitan District, and the Philadelphia Metropolitan area beyond the year 2000 A.D. This project, in its ultimate objective, would obviate the need for use of any of the waters of the Hudson River.

The rapid growth of industry, the introduction of new industries, technological advances, and the introduction of air conditioning and temperature control processes in industry have made enormous demands on water resources. The use of water for agricultural purposes is increasing likewise, in the East as well as in the West.

There appears to be no prospect that this trend toward increased use of water will be halted or reversed in the near future. Each new industrial process will require water and some of them, such as the application of nuclear fission as a source of energy, and the hydrogenation of coal and oil shale, will require enormous amounts. No figures are available for the probable use of water in harnessing atomic energy, but it appears that it will be very large.

Improvement in Water Utilization Practices Needed

An assumption that on long-term basis our total water supply will show no significant up or down trend entails a further assumption that at times the supply will be less than at present. We must, therefore, investigate ways and means of stretching our water supplies through improved utilization practices.

The runoff of the Ohio, Missouri, and Columbia Rivers during the water year was well above normal. The runoff of St. Lawrence River below Lake Ontario was only 9 percent above normal, and slightly less than in 1949, despite the fact that runoff into the Great Lakes was substantially greater in 1950 than in 1949. Much of the increase in runoff into the Great Lakes during 1950 remained in storage, as lake stages averaged about 0.8 foot higher than a year earlier. The runoff of Colorado River was below normal, even though the flow of Green River, one of its major tributaries, was above normal.

Reservoir storage as of September 30, 1950, was generally at or above the average of record for September 30, with the exception of irrigation reservoirs in the West, the aggregate storage in which is below average. The most critical situation, as far as irrigation storage is concerned, exists in parts of Colorado. In California the situation is generally improved over a year ago, except in the southern part of the State.

The pattern of stream flow in relation to normal for the water year ending September 30, 1950, has continued through October with few changes. Runoff in the Pacific Northwest continued above normal, with record-breaking high average flows for October occurring in southwestern Oregon and northern California. The drought in the Southwest continued, with record-breaking low monthly flows occurring at several points in Arizona. Above-normal runoff continued in a wide area between Louisiana and Pennsylvania. Runoff in the coastal States north of New Jersey continued below normal.

We wish to emphasize that water is a renewable resource even though it does not always renew itself in the same place. If Adam had measured all of the water on earth at his time, and if we measured all of the water today, there probably would be little difference in the two totals. As a matter of fact, the water we drink today may have been Cleopatra's bath-water yesterday. However, regardless of their source, rain and snow fall on our land, in ever variable patterns, but in aggregate amounts that we believe are substantially the same as when Christopher Columbus first touched these shores. But it is up to us to make planned—not haphazard—use of what we have.

Large quantities of water are lost every year through non-beneficial consumptive use by certain phreatophytes, or water-loving plants. Salt cedar and other phreatophytes, for instance, have become a serious problem in the Southwest. It has been estimated that nearly 300,000 acre-feet of water is consumed annually in this manner in the Rio Grande and Pecos River Basins in New Mexico. This would support a city of one and a quarter million population at a rate of over 200 gallons daily per capita. This does not necessarily mean, of course, that if the phreatophytes were destroyed the entire 300,000 acre-feet of water would be made available to stream flow. Nevertheless, these figures point to the fact that an opportunity exists to augment our water supplies through greater control over non-beneficial uses. In the selection of storage reservoir sites more consideration is being given, particularly in the West, to the question of evaporation. Steps also are being taken to determine the feasibility of reclaiming water from sewage and from the sea.

In 1888 Congress made the first small contribution to the U. S. Geological Survey to explore the water resources of the West. During the debates, Major Powell, then Director of the Geological Survey, made the following statement in the course of his remarks:

"You cannot lay out lines and stakes in the clouds of the heavens from whence the waters come. They pour down today in storms and tomorrow in storms, and during the year in storms, and flow down to the rivers and creeks, and you have to measure them out by gallons or by acres from day to day, from month to month and from year to year."

If Major Powell were alive today he possibly would not make the same statement, in view of the attacks that have been made on the clouds by a people thirsty for water.

As we already have heard at this meeting, this important question of producing rainfall by artificial release from the atmosphere has been given serious attention by scientists for quite some time. Although still in the experimental stage, it is conceivable that methods of

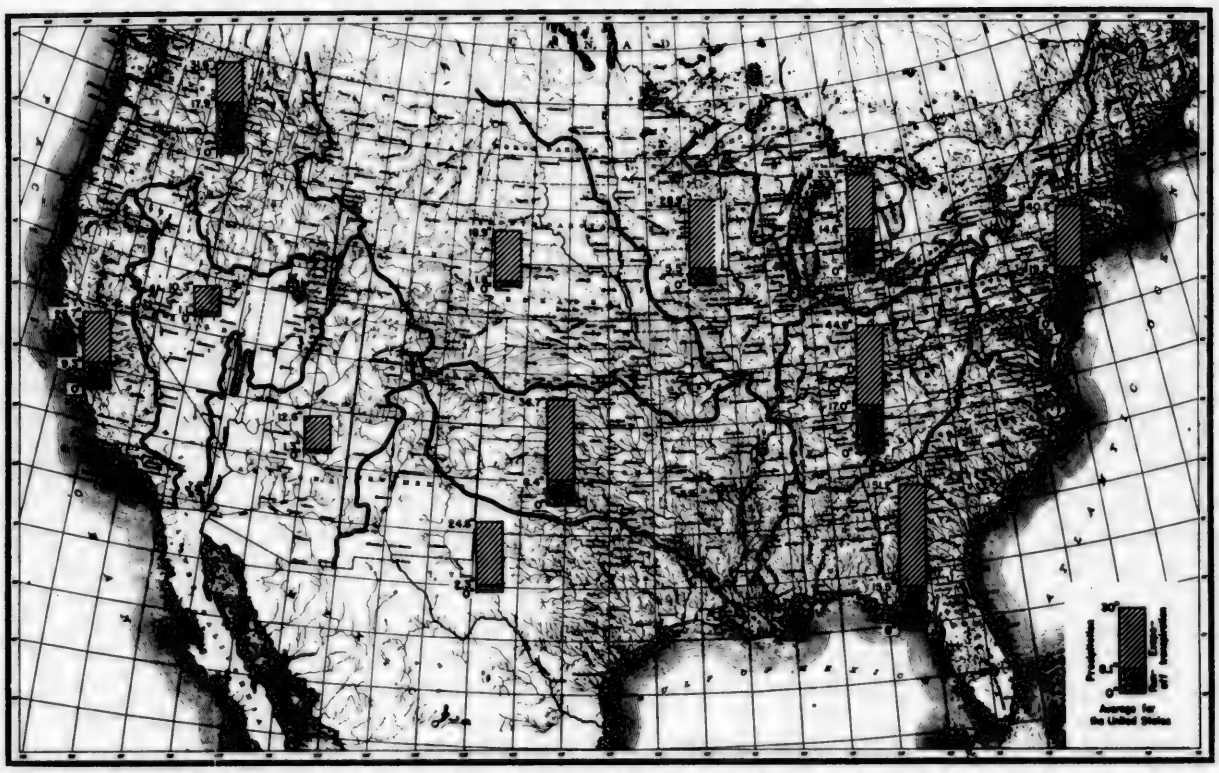


Figure 2. Precipitation, runoff, and evapo-transpiration by major drainage basins. U. S. Geological Survey, Department of Interior.

practical application for specified areas may be developed. Future developments of this process will continue to be watched with interest by all who realize that our water supply is not limitless.

The question of the control of natural conditions that affect water occurrence leads to a related question that has been the subject of study for many years—the effect of forest cover on maximum, minimum, and total runoff, on the time of distribution of runoff, on ground-water supply, and related factors. Many studies have been made to determine this effect under varying conditions in various places, and much has been learned. So far as we are aware, however, no all-embracing conclusive answer has been found, although the effect upon soil erosion is more conclusive. It appears that every water-shed is a problem in itself, in which land-use practice must be governed by the conditions on that particular water-shed. Further studies are needed to determine the pertinent comparable characteristics between water-sheds, and the factors that may be transposed between water-sheds of unlike characteristics.

Sedimentation is another phenomenon that is being studied, not only by the soil conservationist, but by the hydrologist and the engineer as well. It is part of the water-supply problem because it affects the usability of the water. The U. S. Geological Survey is operating sediment stations at about 150 points on streams in the United States in order to determine the suspended sediment being transported by water. The resulting data are used for many purposes, including studies of reservoir siltation, channel aggradation, and effect upon municipal and industrial use. Another paper on this panel explores this subject more fully and it will not be further discussed here.

Present Stream Flow Compared with Normal

The accompanying figure shows pictorially the magnitude of runoff in percent of normal at selected points during the water year ending September 30, 1950. The normal flow of a stream is an arbitrary quantity, and it can vary between wide limits, depending on the period of record upon which that normal is based. Furthermore, comparisons of the normals of several streams are meaningless unless those normals are based upon the same period of record. Normals referred to herein are averages for the 25-year period October 1, 1920, to September 30, 1945—or, in other words, for the 25 water years from 1921 to 1945 inclusive. For technical reasons, that

(*Continued on page* 100)

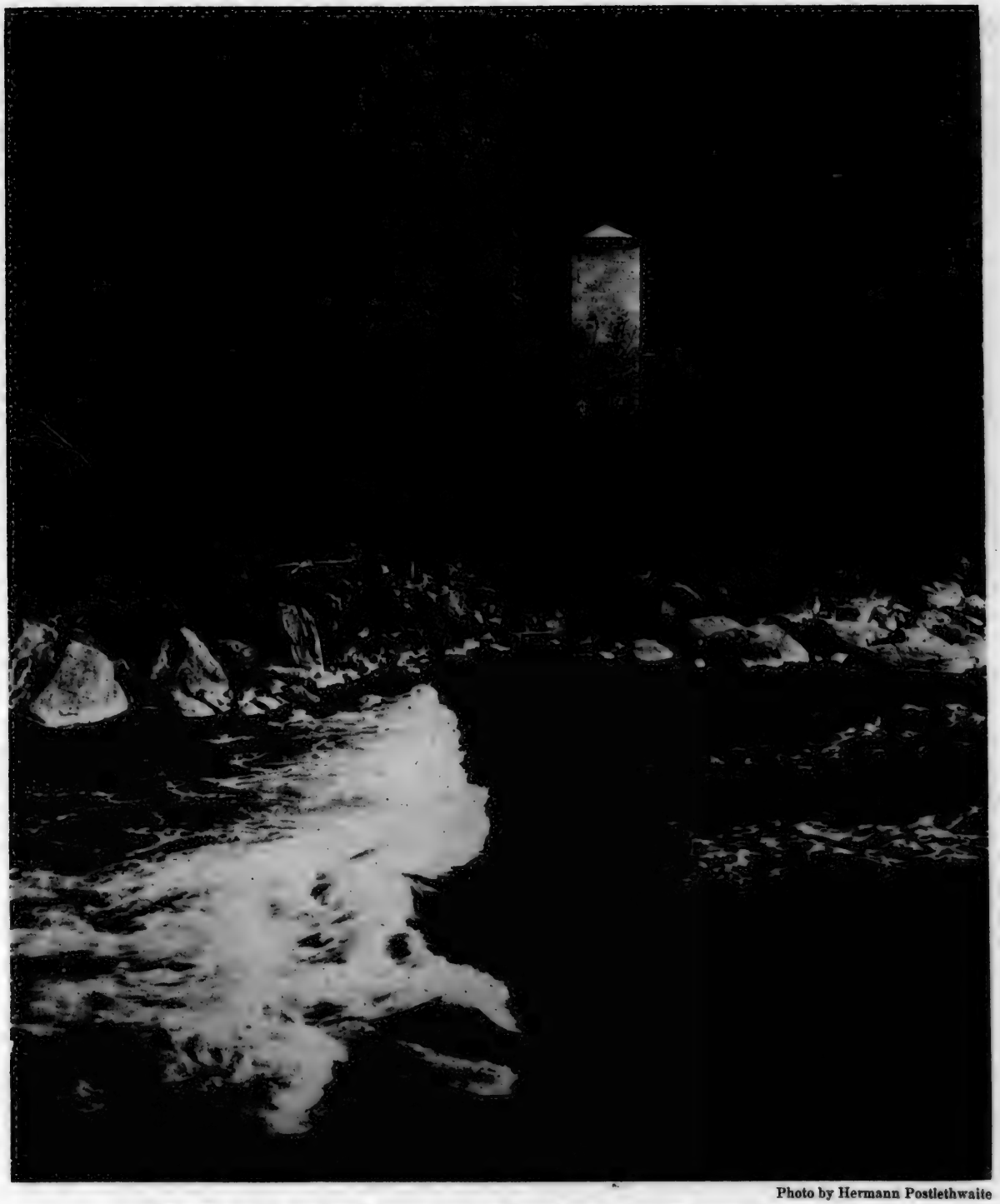


Photo by Hermann Postlethwaite

A Flow-Gaging Station and Recorder on the Brandywine River, Delaware. The Brandywine Valley Association, in its research activities, found it highly desirable to measure the amount of silt or topsoil lost from the Brandywine drainage area.

Photo by Gordon S. Smith

A hunter shooting at a cock pheasant flushed from a contour strip next to a multiflora rose hedge on the J. Kreider farm near Quarryville, Lancaster County, Pennsylvania.

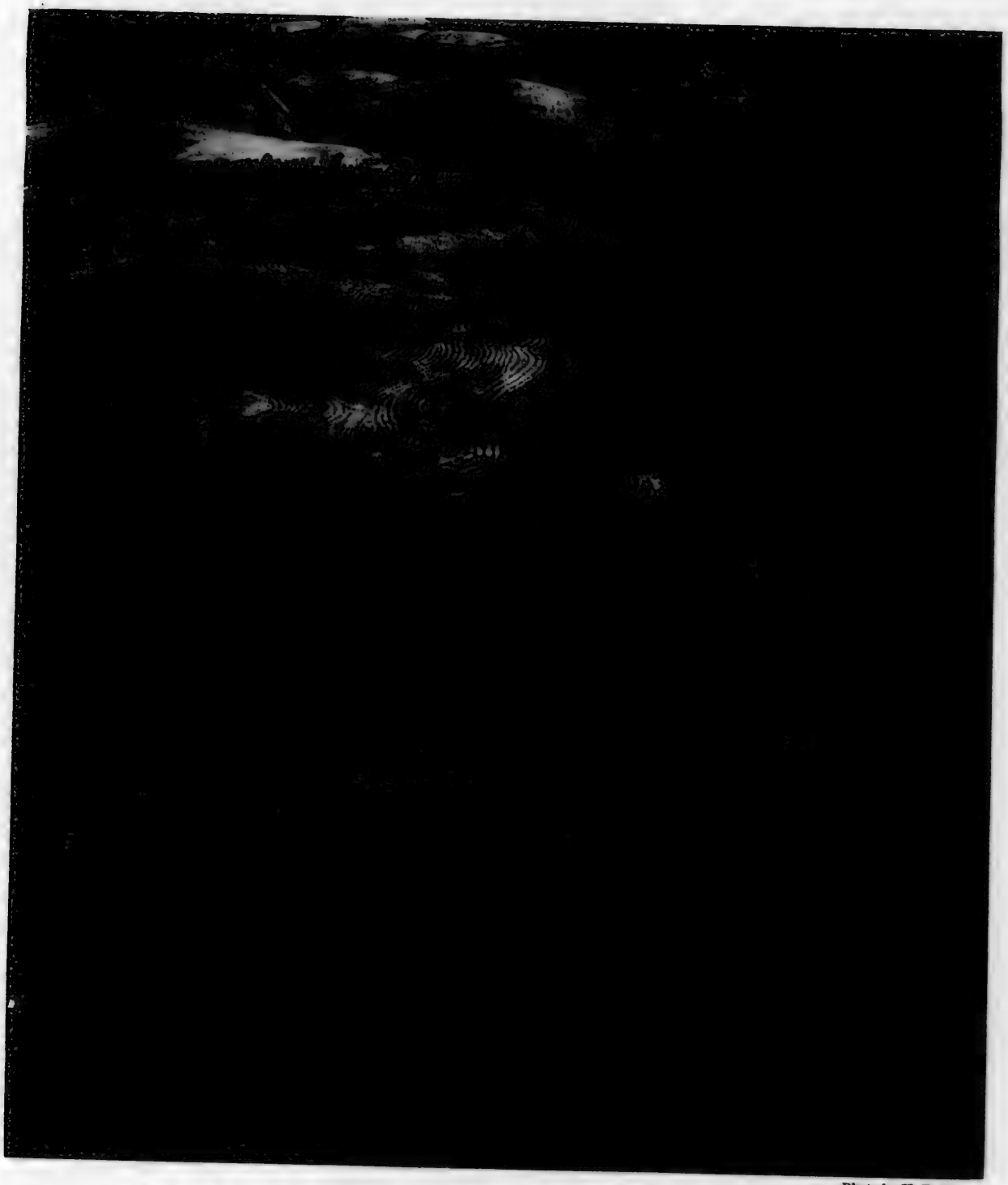
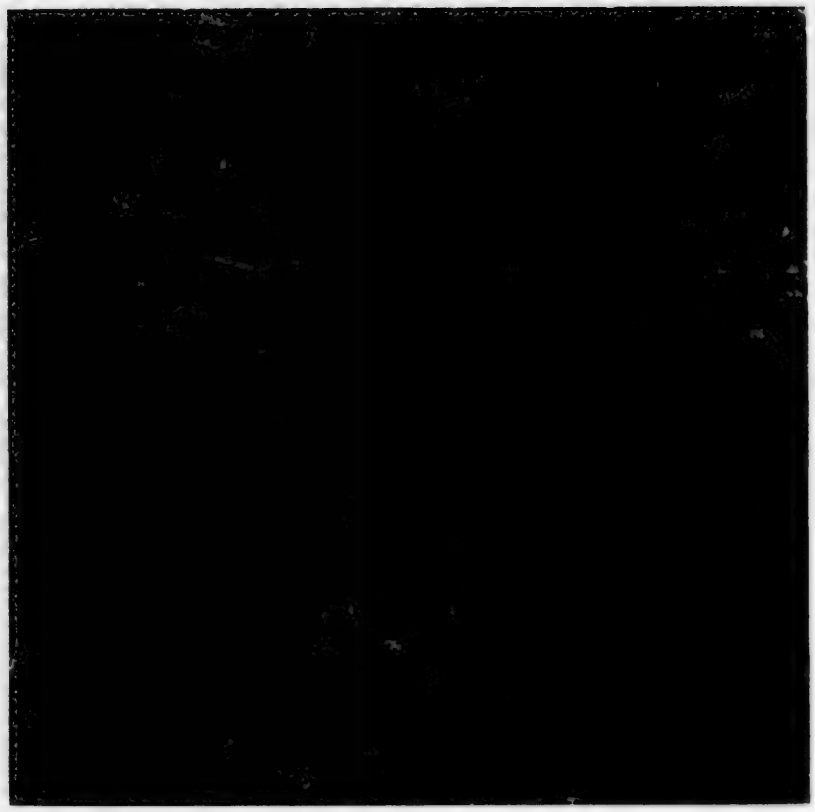


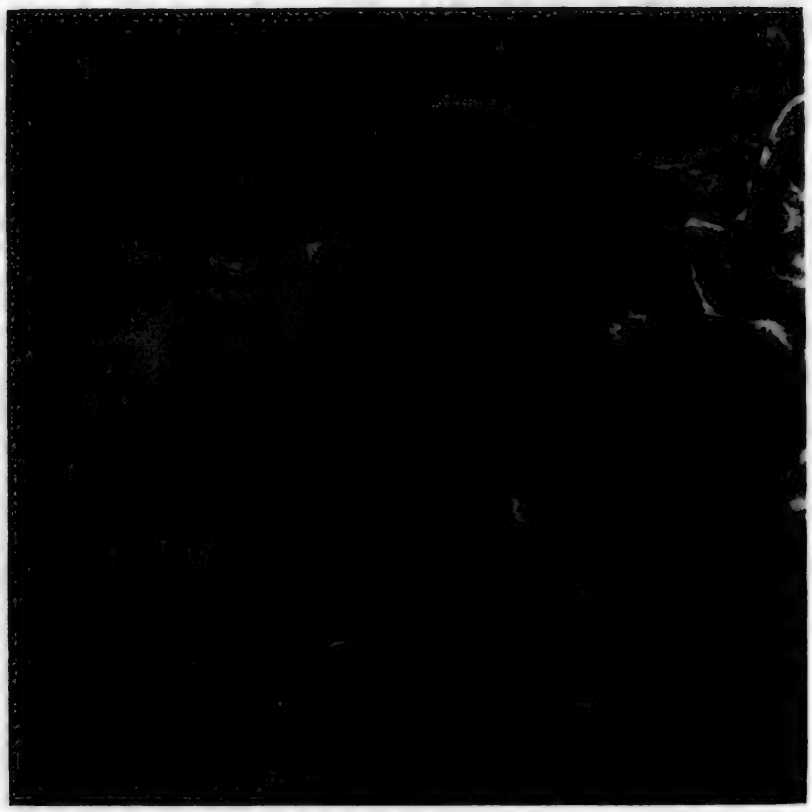
Photo by H. F. Culver

This aerial photo shows a contour forest plantation along the shores of Lake Leesville in the Muskingum Conservancy District, Ohio. Here is an excellent example of good land use in watershed protection.

The two photographs reproduced on this page were sent to the JOURNAL by A. de. Vajda, Chief Conservation Engineer, Damodar Valley Corporation, Hazaribagh, India. Mr. Vajda is also an active member of the Soil Conservation Society of America.



An aerial view showing a badly gullied area in the Damodar Valley before the land was reclaimed for agricultural purposes. The average rainfall in this section totals 53 inches—80 to 90 percent coming during the three monsoon months. Soil erosion caused by improper land use and uncontrolled water has greatly depleted and in many sections completely destroyed the land. Floods are also common in the valley.



This *"after"* photograph emphasizes bench terraces for the production of rice. The terraces are 18 to 24 inches high and are built to hold six to nine inches of standing water. In addition to checking soil erosion and slowing the runoff of water, they also contribute much in helping to overcome critical food shortages in India. An earthen dam backing up 170 acre feet of water for irrigation purposes is clearly visible in the upper part of the photograph.

What Determines the Value of Water?

GEORGE D. CLYDE

People throughout the land are becoming water conscious. They recognize, points out Dr. Clyde, the limit of the growth of this nation will be its water supply—already new sources of supply are being considered. "Research," says the author, "is being directed toward cloud seeding, making water potable, salvaging sewage and industrial wastes, recharging underground aquifers, and other methods. All of these methods of increasing water supplies will be extremly costly. In the end such costs may fix the market value of water but not the real value. This depends upon its use and conservation.

WATER IS A REAL substance. It has value by virtue of its presence and its use. Water rights are recognized as real property. Two fundamental doctrines of law have become established. The first is called the *Doctrine of Riparian Rights,* which literally says that a man owning the bank of a stream is entitled to have the water in the stream flow by his property unpolluted in quality and undiminished in quantity for all time. This literal interpretation has been modified to allow for reasonable use among common owners. The second is called the *Doctrine of Prior Appropriation.* This doctrine says, "First in time is first in right and beneficial use is the basis and the measure of the right." This doctrine permits the body of the water to be used up.

Water rights throughout the land have been established, based on one or the other of these basic laws. Multiple use developments will require changed uses. Water rights may have to be consolidated. Values have attached to the different water rights. These water rights are subject to being bought and sold. Such transactions require the establishment of the value of water rights. Such values are in part dependent upon the source, characteristics and uses of water.

Source, Uses and Characteristics of Water

Water is universal. It is a major part of the living thing. Its value and importance to the people of the world cannot be over-emphasized for all life ultimately depends upon water for its very existence. Where water supplies are deficient, unstable or polluted, civilization's progress is seriously retarded.

The ultimate source of water is precipitation which falls in the form of rain or snow. Much of the precipitation is transpired by plants or is evaporated back into the atmosphere. The balance collects and forms the surface streams or is stored in the soil or underground aquifers. It is from surface streams or underground sources that man obtains his water supplies.

Surface streams, including springs, have different characteristics. Snow-fed streams or springs begin to rise at the beginning of the snow melting season and recede after the disappearance of the major portion of the snow cover. Their period of high flow is relatively long. Rainfed streams rise during or immediately following the rain, usually peak higher and have a period of high flow of shorter duration than the snow-fed streams. Both types of streams have relatively long periods of low stream discharge. A knowledge and control of the seasonal amount and distribution of both types of flow is essential to maximum use and greatest value.

Ground water supplies are already in storage. Ground water, which is subject to the force of gravity and which occupies permeable formations, provides a stable source of water for man's use, subject to the limitations of the average annual recharge.

When people began to live together in communities, one of their first problems was to find and develop a water supply to meet the domestic and municipal needs. Sanitary sewers, modern plumbing, spinner type washing machines and air conditioning have greatly increased the use of water by the human family. Today cities could not exist without a stable municipal water supply. Great cities were first established on waterways or on the sea coast. Navigation furnished the first means of transportation for people and goods. Since the earliest times, water has been used to generate power and today hydroelectric power is one of man's greatest assets. Great industries are dependent upon water supplies, not only to furnish power, but for use in the manufacture of steel, in the chemical industry and oil refineries, in paper mills and rubber plants, in stream power generating plants and in the processing of food, fiber and drinks. For example, a large paper mill will use 50 million gallons of water a day, more than enough to supply a city of 500,000 people. It takes 600 to 1,000 gallons of water for each ton of coal burned in a steam power

This paper by George D. Clyde was presented at the annual meeting of the Soil Conservation Society of America held in Detroit, Michigan, October 26-28, 1950. Mr. Clyde is Chief, Division of Irrigation, Soil Conservation Service, Logan, Utah.

generating plant and 65,000 gallons of water for each ton of steel produced. It requires 25 gallons of condensing water to produce a gallon of aviation gas and 85,000 gallons of water to produce a ton of rubber.

The most universal use of water, in addition to human consumption, is to support plant growth. Over much of the earth this moisture falls naturally as rain and is taken directly into the soil, where it supplies the needed moisture. There are large areas, however, principally in the temperate zone, which are arid or semi-arid and in these areas the successful production of crops is dependent upon the artificial application of water to the soil. Water may be used consumptively or non-consumptively. The principal consumptive uses are domestic, municipal, industrial and for irrigation. The non-consumptive uses are power generation, recreation, wildlife and navigation.

Water is a recurring resource. It is here today and if not used, it goes on its way to the sea. Tomorrow or next month or next year more water is here again. In quantity and time of occurrence it varies widely but is subject to control by man. Water may be an asset or a liability. It is an asset when controlled and put to use for domestic and municipal purposes, to supply moisture for plant growth, to generate power, to supply water needs for industry, to support wildlife and recreation and to provide for navigation.

Conversely, water has a tremendous destructive power. Uncontrolled it is an erosive agent. It can move the top soil and cut channels and gullies through the earth mantle. It can destroy farms, cities, roads and all the works of man erected in its path. Water is a universal solvent. It quickly dissolves the more solluble portion of the earth mantle and causes salt accumulation in harmful concentrations. Water is a serious liability when it causes floods, erosion, waterlogging of land and accumulation of harmful salts. It is like a double edged sword. Under control it is one of man's greatest assets. Out of control it becomes a destructive agent and one of man's worst enemies.

Thus, the value of water may be *positive* or *negative* and is a function of its use.

Priorities of Use

As demands for water for human, agricultural, power, industrial and recreational purposes increase, multiple use projects will become necessary to fully develop the water resources of an area. Such projects immediately raise questions of priority of use. Which use will return the greatest value to society? This question was recently raised by the President's Water Resources Policy Commission. In the West, the most commonly accepted order of priority is domestic and municipal, irrigation, power industry, recreation, wildlife, and navigation. The growing demand for water and critical shortages that are developing in the various areas has prompted a critical review of this order of priority. The priority should be influenced by the value to society, both tangible and intangible, of the water. One group (1), in replying to the President's Water Commission had this to say: "In those areas where water supplies are inadequate to accommodate all of the desired uses, it is our opinion that such use which will contribute most to the economic and social welfare should have first claim to the water. We have long recognized that water for domestic purposes takes precedence over use for irrigation or industry. Similarly, in the future we think that in many areas there may be a gradual shift from the use of water for irrigation to uses for industry. While there may be some lag in making the adjustment, in most cases this shift can and will be made naturally, based on the ability of the new use to return a larger income from the use of that water than could the existing uses. We think that it would be a mistake to so fix the use of water that it could not be shifted as general economic and technological conditions change."

The Water Potential

The value of water depends upon its use. To have value for municipal purposes it must be available to a municipality and be of satisfactory quality. I have often looked at a beautiful bubbling spring of clear water issuing from the rocks in a mountain gorge located far from human habitation and inaccessible to any town or city. Its value for municipal, power, industrial and navigation uses is zero. It flowed into a stream and far below was diverted for irrigation. Its value is fixed by its agricultural use. If it were accessible to Los Angeles, California; Lubbock, Texas, or any other large municipality, its dollar value would be many times its present value.

Usually the conditions surrounding a water suppiy may be changed. For example, the water may be conveyed long distances to a point of use; it may be put into storage for later use; or it may be treated to remove silt or bacteria. Regardless of the changes, the value of the water is fixed by its use at point of application. The cost of development and control is a part of the value and may be the minimum value but does not alone fix the value. The difference between the benefits resulting from use of the water and benefits obtainable without the use of the water is a measure of its value. These benefits are difficult to evaluate in terms of money.

Every water supply has a potential value. Let's call it a "water potential." This water potential is not fixed.

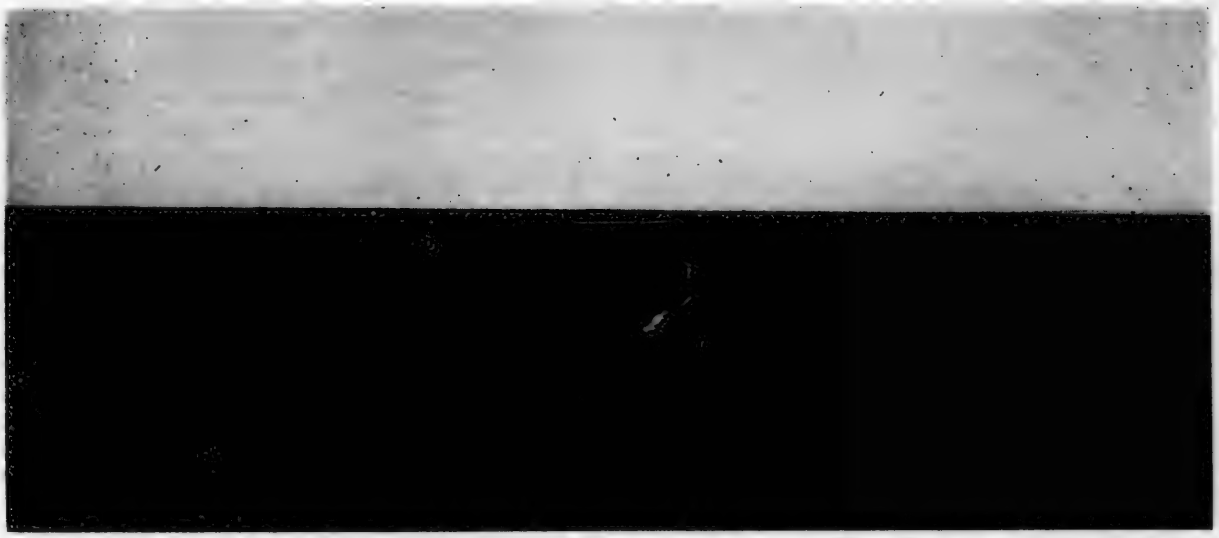


Figure 1. This scene in Nevada shows land being cleared for irrigation purposes. The willows to the right of the drain were as thick as those to the left before clearing.

It can be modified by man because water can be controlled and transported and its quality improved. It can be used for a multitude of purposes. Use determines its value.

Factors Which Give Value to Water

How much is water worth? It depends upon the water-use relationship.

Domestic and Municipal Use. For human use the value depends upon the extent of the need. If you are dying of thirst, no value is too high. If New York's water supply was in jeopardy, she would spend huge sums to make it adequate and stabilize it. Cities can grow in population and industrially only as fast as they can increase their water supply. Therefore, rapidly growing cities like Lubbock, Texas; Phoenix, Arizona; Salt Lake City, Utah; Los Angeles, California; and others are willing to pay heavily for adequate municipal water supplies. The minimum value to them is what they have to pay for it. The actual value is far greater and cannot be measured in dollars alone.

Agricultural Use. For agricultural use, water has its greatest value in areas of low rainfall. Soil, water and climate are the most important factors producting plant growth. Without water no plants can grow. Assuming a Class I soil and a favorable climate, water becomes the limiting factor in fixing the basic land values (2) and crop production. In an arid climate such as Arizona, crop production without water is essentially zero. Therefore the net value of the crop (the selling price less cost) divided by the acre feet of water used would be one way of computing the value of water per acre foot.

The value of a water right depends upon its availability during the irrigation season because its availability governs the crops that can be grown. When an adequate water supply is available during the entire irrigation season, a second foot of water is worth far more than when there is an excess of water during the early spring and a shortage during late summer. The value of a stream of water for irrigation purposes also depends upon its location, type of crops raised and the cost of marketing such crops because these factors help determine the cost of producing the crop.

It appears, then, that the true value of water depends on its effect on the productive capacity of the land on which it is used. Some of the factors which determine this effect are:

1. Quantity of water available.
2. Seasonal distribution of water.
3. Quality of water available.
4. Climate.

The total quantity of irrigation water available should be sufficient to meet the net consumptive water requirements of the crop plus reasonable unavoidable losses inherent in the water management practice being followed. This amount will vary with crop, climate and irrigation efficiency. In Utah this amount may average three feet per acre per year while in Arizona it may average seven acre feet per acre per year. The amount considered adequate would be fixed by local conditions. For example, in Arizona, if seven acre feet per acre per year were available on demand, this water supply would be adequate to produce any crop grown in the area. Such a water right would be of the highest value. This value, however, would not be fixed by the cost of pro-

viding it but by the difference in the net value of the crop produced with it and without it.

Where water supplies are limited, the yield per acre foot of water is more important than the yield per acre. For most crops, alfalfa excepted, the yield increases with increased water application up to a peak and then decreases with further application of water. Karl Harris, Irrigation Engineer for the Soil Conservation Service, Phoenix, Arizona, showed in Arizona that a total application of seven acre feet of water per acre produced 1.3 tons of alfalfa per acre foot and a total application of 11 acre feet per acre produced only .9 tons per acre foot of water. Water has the greatest value under conditions which yield the greatest return per acre foot.

Crops require different amounts of water at different seasons. When the plants are small, the water requirement is low. As the season advances, temperatures rise, plants grow larger, have more leaf surface and evapotranspiration is higher. In the Intermountain area the demand for water by the plant is low in May, increases through June, reaches a maximum during July and August and drops down during September. The natural flow of most streams does not coincide with the water demand by the plants. The water right whose seasonal distribution is equal to the seasonal crop demand is the one of greatest value. If the supply of water is available only up to July 1, limited crops can be grown and the value of water is lower. By storing water in surface or underground reservoirs, the supply can be made to conform to the demand and the value of the water becomes greater.

The quality greatly affects the value of water. If it carries a heavy silt load, the maintenance of canals and laterals is greatly increased. If it contains salt, it may cause soil changes affecting water movement through the soil. It may be toxic to plants and the use of such water may require tile drainage and leaching to maintain proper salt balance. Soil amendments may be necessary. Water of poor quality reduces yields, increases costs of production and reduces net return from crops. Such water has a lower value than water of good quality.

Climate has a major influence on the value of water. It fixes the length of the growing season. If the growing season is long, a wide variety of crops can be grown, making the return from water large. For example, a 90-day growing season will limit crops to small grains, alfalfa, and forage. A growing season of 145 days will support corn and similar crops. If 180 days are available, cotton can be grown, and if 250 days are frost-free, citrus can be grown. Greater yields and higher value crops can be produced in long growing seasons. Water, therefore, takes on a much higher dollar value.

There are other values, however, that must be taken into consideration. People live in areas where the growing season is short. They will continue to live in those areas because of the human, social and economic conditions involved. Water which may have a relatively low dollar value when used in those areas, must continue to be used there in spite of the fact that it would have a higher dollar value if it were taken to the long growing season areas. For example, if the dollar value alone governed and no prior water rights were involved, little water would be used in the Upper Colorado River Basin because there is a surplus of good land and a long growing season in Arizona and California.

Examples of Direct Value of Water for Irrigation

The following figures are based on the general principal that the value of water for irrigation is equal to the net value of the irrigated crops minus the net value of dry-land crops on the same land divided by the acre feet of water used:

In Payette, Idaho (3), on the reclamation project in 1946, the Bureau of Reclamation reports a net farm income of $84 per acre. The climate is arid and crop production without irrigation is impossible. If their average irrigation use was three acre feet per acre, the value of water per acre foot would be $28. This does not include the indirect benefits that are represented by the value to the communities supported by the irrigation agriculture in the area. In the Payette area, the indirect benefits were estimated by the Bureau of Reclamation to be $107 per acre, making the total benefit or value of water $63.70 per acre foot.

In the Salinas Valley (4), in California in 1947, intensive studies of cost of production of agricultural crops were made. In this valley the return from crops without irrigation was shown to be very low, whereas the return from crops irrigated during that year was found to give a net value per acre foot of water used of $54.86. It is to be recognized, however, that these net values of water per acre foot will vary with the income per acre of irrigated crop and, therefore, will vary from year to year. For example, in 1941 the value of water per acre foot in the Salinas Valley was only $6.30.

It is generally recognized that the excess of the income over the cost of production in an irrigation agriculture is a measure of the value of the water but the reported recommended permissible annual cost of irrigation water is much less than this difference. (5) This is necessary to cover the fluctuating annual incomes due to varying yields, costs of production and prices.

The following quotations are taken from an appraisal of a water right by a Salt Lake City Consulting Engineer and show the difficulty of establishing a firm base for fixing the value of water:

Case 1. "*Value of Water Rights:*—Storage water usually has a higher value than direct flow right water as the former can be drawn on as and whenever the user desires, while direct flow water must be taken when owner's turn comes whether he wants it or needs it and if not then taken the user loses his turn. The value of storage water also depends on the percent of the stored water he can actually get onto his land, as well as the locality in which the water is used, the irrigation season, type of crops raised and cost of marketing these crops. In the right under consideration, the water is used primarily for hay and grain crops which have a low net value on account of their marketing cost. Again, in the writer's opinion, not over fifty percent of the water stored is available for actual irrigation use on account of large loss in transit. Furthermore, it was evident to the writer that sooner or later considerable maintenance and repair work will have to be done on the impounding dam. Taking all these factors into consideration, the writer is of the opinion that the storage water in this reservoir is at the present time worth not to exceed $6.00 an acre foot. On the basis of a normal storage supply of 1000 acre feet this right is worth $6,000."

Case 2. "*Value of Water Right and System:*—From the standpoint of a culinary water system for Widtsoe this system has a value of between $5,000 and $6,000. However, after the town is once abandoned this system has absolutely no value as a culinary system because there will be no need for same. From an irrigation standopint the water right has very little value for the reason that the amount is too small for practical irrigation use. It could be mingled with Sweetwater Creek water for irrigation use and as such it would not be worth over $75. The system has no salvage value as it would cost as much to take up the pipe as the pipe is worth. The writer was informed that the owners have offered to sell the water right and system for $3,000. There may be a moral question involved in the abandoning of this culinary system, inasmuch as the removal of the town is destroying the market for the system."

The value of water for irrigation seems to be proportional to its scarcity. The more limited the water supply, if under complete control, the greater its unit value. Water values follow the law of supply and demand.

Figure 2. A panoramic view of land leveling nearly completed north of Bull Run River, Elko County, Nevada. This operation represents nearly 200 acres of land.

In Cache Valley, Utah, there are two parallel canals. One has an early right with plenty of water. The other has a later priority with plenty of water in the spring but a deficient water supply in later summer. The water rights are represented by shares of stock in each company. The acre feet of water per share of stock is greater in the first company. The value of stock in the first company is $60 per share and in the second company $120 per share.

The great drought in the West in 1934 was a blessing in disguise to many areas. It showed the water users the value of their water resource. Immediately they began using it more efficiently. They recognized that if they had advance knowledge of this seasonal supply they could plan to use it more efficiently, greatly increasing its value to them. They now demand water supply forecasts to supply this knowledge. They found that proper land preparation made possible a more efficient use of their water. They began to level their land. Their water supply increased in value because they could produce more crops at less cost. Those who had small streams found the use of farm reservoirs greatly increased the efficiency of use of their water and reduced the cost of water application. Their water became more valuable because of the greater return per unit of water applied. Every case is a special case and requires full consideration of the water-use relationship.

The Petan Land and Cattle Company in Elko County, Nevada, owns several thousand acres of bottom land along Bull Run Creek and the Upper Owyhee River. As a part of their land holdings the entire stream flow on these two tributaries were acquired. Under the original management of the ranches along these two streams

(*Continued on page* 106)

Sediment Steals Water Storage

CARL B. BROWN

Many writers on conservation subjects, points out Mr. Brown, have predicted the early ruin of costly multiple-purpose reservoirs because of sedimentation, unless action is taken at once to control watershed erosion. Watershed planning is the key to translating this concept of sediment control into reality with the greatest effectiveness in the shortest time at the least cost. To accomplish this, four factors must be recognized. They are: hydrologic controls of the drainage basin, hydrologic control units should be divided into sub-watershed planning units, a plan of treatment should be prepared, and all farm and ranch land should be used according to its capability and treated according to its need.

STORAGE RESERVOIRS are an indispensible part of the Nation's economy. Approximately 10,000 reservoirs larger than farm pond size have already been constructed in the United States for power, irrigation, flood control, municipal and industrial water supply, navigation, recreation and other purposes. These reservoirs are estimated to have cost five billion dollars. The average cost of replacement, where substitute sites are available, would be several times the initial cost. Currently new reservoir construction, mainly by the Federal Government, is proceeding at a rate of more than one-half billion dollars annually. Only about ten percent of the Nation's reservoirs have capacities of more than 5,000 acre-feet. Only about three percent of the Nation's reservoirs are Federally-owned and operated, but they contain about three-quarters of the estimated aggregate developed storage capacity of 200 million acre feet. In other words, most of the Federally-owned reservoirs are large and a majority of the largest reservoirs are Federally-owned.

Storage reservoirs provide the domestic water supply for nearly one-half of the 80,000,000 persons who use surface water—and nearly half of our industry. Reservoir construction has taken a large share of the 2.5 billion dollars already expended for flood control and will take a larger share of the additional 7.1 billion dollars authorized to be expended. Reservoirs regulate stream flow at most of the hydro plants which produce 29 percent of our total electrical energy. They make possible the irrigation of much of the 22,000,000 acres now artificially watered and even more of the 13,000,000 acres involved in projects now underway or under consideration. They make possible navigation on much of the 24,000 miles of inland waterways. They provide pollution abatement on many streams. And they are an important factor in the estimated ten billion dollars spent (in 1949) for recreation on lakes, rivers and other water areas.

All reservoirs are subject to loss of storage capacity resulting from deposition of stream-borne sediment. The rate of storage loss in individual major reservoirs ranges from a negligible fraction of one percent to more than three percent annually. The present average loss of storage in the Nation's reservoirs is of the order of 350,000 acre-feet annually. With the accelerated programs of reservoir construction now underway, mainly by the Federal Government, and in the absence of more far-reaching efforts toward watershed protection, the average storage loss may be expected to reach 600,000 acre-feet annually within a decade or two.

Although the title of this paper relates to stealing, its theme is crime prevention—namely, reduction of the Nation's loss of irreplaceable water storage facilities to tolerable proportions.

Missouri River Basin Development

In order to particularize this problem let us consider the Missouri River Basin—a vast area 1400 miles long and more than 600 miles wide, covering approximately (Figure 1) one-sixth of continental United States.

Prior to 1941, more than 1100 reservoirs, having an aggregate capacity of some 30,000,000 acre-feet, had been constructed in the Missouri Basin. Most of them were small. Nearly two-thirds of this total storage was in Fort Peck Reservoir, built by the Corps of Engineers in the mid-1930's on the upper Missouri River in Montana. The available surface water supply of 45,000,000 acre feet in the Missouri Basin was insufficiently regulated for flood control, irrigation, power, navigation, municipal supply, pollution abatement, recreation, fish and wildlife and other purposes.

During World War II the Corps of Engineers and the Bureau of Reclamation prepared separate river basin development plans. These were eventually consolidated into the now well-known "Pick-Sloan plan" which was

Carl B. Brown presented this paper at the Annual Meeting of the Soil Conservation Society of America held in Detroit, Michigan, October 26-28, 1950. Mr. Brown is Sedimentation Specialist for the Soil Conservation Service with headquarters in Washington, D. C.

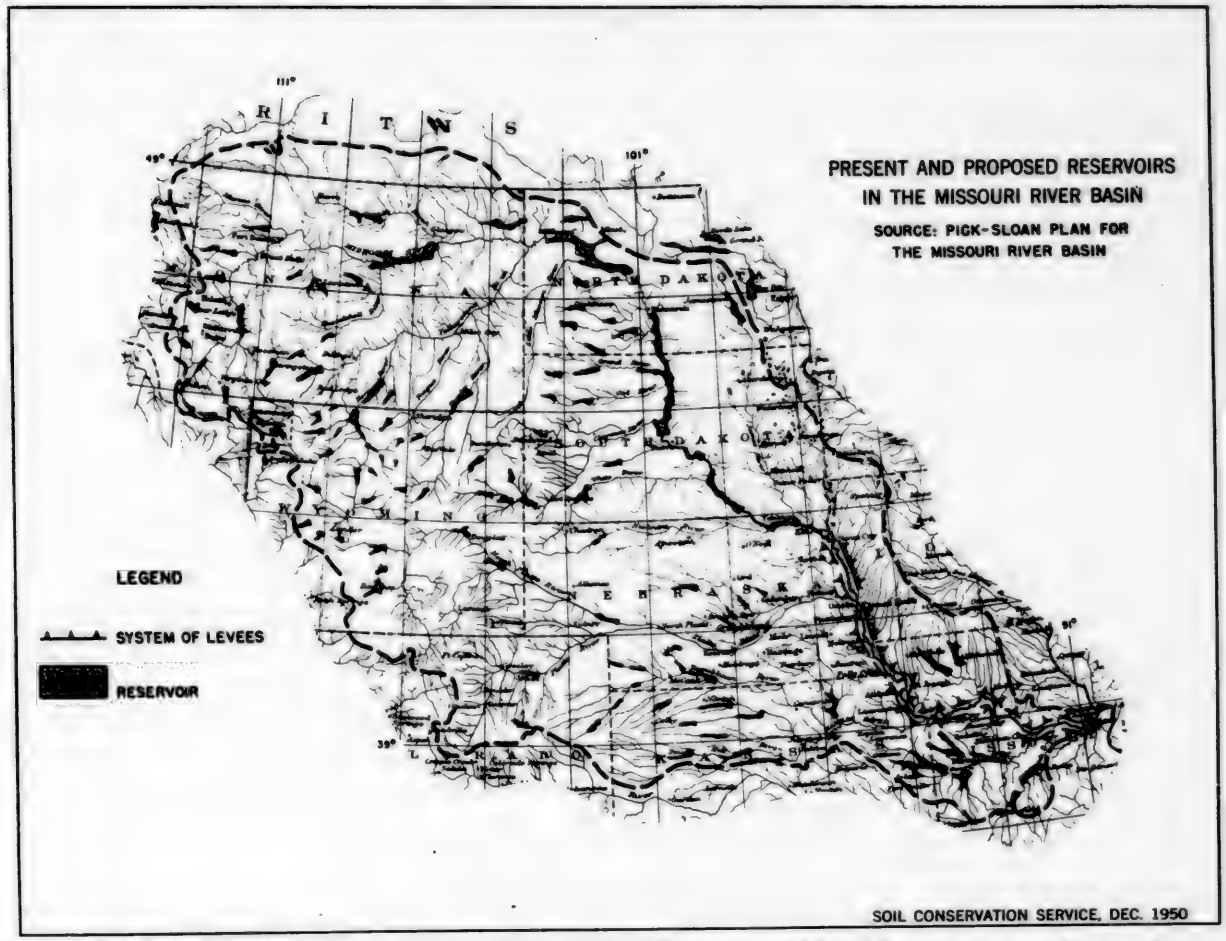


Figure 1. The Missouri River covers approximately one-sixth of the continental United States. Present and proposed reservoirs for irrigation are shown on the map.

authorized in the Federal Flood Control Act of 1944. The total cost of the works outlined in this plan were estimated to be about $4.5 billion at then existing prices. Still other projects going beyond the scope of this plan are now under intensive investigation by both the Corps of Engineers and Bureau of Reclamation. The original plan was designed to protect six million acres from flooding, provide 10.7 billion kilowatt hours annually of additional electrical energy, provide for irrigation of five million acres of new land and supplemental water supply for another half million, provide and regulate the water supply for a navigable channel nine feet deep and 300 feet wide from Sioux City to St. Louis, and various other benefits, such as municipal water supply, pollution abatement, recreation, etc.

The Pick-Sloan plan with the additions now under consideration may include as many as 150 reservoirs having an aggregate storage capacity of more than 100 million acre feet. Together with the existing reservoirs they would provide nearly three acre feet of storage for every acre foot of annual water yield in the Basin.

The Problem of Reservoir Silting

Much has been said pro and con about the urgency of the reservoir silting problem. Responsible officials of Federal agencies have recently made the following statements about sedimentation in Federally constructed reservoirs: "These reservoirs will serve mankind just about as long as water runs downhill" and "liberal allowances have always been made for the capacities which would be destroyed by silt accumulations within the reasonable life of the reservoirs. With the information . . . available . . . there is yet no concern by responsible persons that the fears often expressed will be realized . . . recent investigation is proving conclusively . . . that our erosion problem has become simply one of flood control and, if we are going to solve the problem in a positive manner and with assurance of success we must realize

that we are attempting to stop a geologic process and that is going to be done only at an enormous cost. In the meantime we must build under conditions as they exist. We have plenty of time to study the problem and if, 100 years from now, we will have found the answers to the whole problem it will be in plenty of time and perhaps by then we can afford to build the enormous works that will be required to stop this geologic process."

On the other hand, many writers on conservation subjects have predicted the early ruin of costly multiple-purpose reservoirs unless action is taken at once to control watershed erosion. Typical is the following quotation from a popular recent book on conservation:

> *"Unless this far-flung process of erosion can be checked throughout the entire drainage basins of our river systems by an attack proportional in magnitude and vision to the projected engineering control program, the costly engineering works that are now envisaged will be doomed to early destruction by siltation . . . the towering dams to be built for flood detention, irrigation, and electric power will become swiftly obsolescent as their reservoirs are filled with silt."*

Between these divergent viewpoints what is the layman to believe? Perhaps a few statistics will aid in bringing this problem into better perspective.

From comparatively meager data now available it is estimated conservatively that the aggregate loss of storage capacity in the 35 major Federally-owned reservoirs that have been completed or are under construction in the Missouri Basin will be approximately 165,000 acre feet annually. This much capacity would hold enough water to irrigate 50,000 acres of land, or supply a city of nearly 1,000,000 population for a year at a consumption rate of 150 gallons per person per day.

However, this annual loss is only .2 of one percent of the total capacity of 85,000,000 acre feet provided in these 35 reservoirs. In other words, if all the storage were in a single gigantic reservoir in which all of the sediment was deposited at a uniform rate it would take 500 years to completely fill the capacity of this reservoir. However, generalizations are dangerous. Individual reservoirs will lose their capacity at rates from as little as .006 to as much as 3.4 per cent annually, a difference of more than 500-fold. Moreover, most of the reservoirs will have lost the greater part of their initial service value when they are 50 to 80 percent silted.

All of the Federally-built reservoirs in the Basin have a storage allocation for sedimentation. This is to say that after sufficient storage was provided to meet specified service requirements on the reservoir for power, irrigation, flood control, etc., an additional amount of storage equivalent to the sedimentation expected during a period of 50 to 100 years has been added, generally, in the lowest or dead storage level of the reservoir. For this reason, the designing engineers maintain that sedimentation will not reduce the primary service value of any reservoir during such a period.

When viewed from this perspective the silting problem may not look too alarming.

Cost of Providing Sediment Storage

On the other hand, the storage allocation for sediment materially increases project costs. In the three major reservoirs under construction on the Missouri River, namely, Garrison, Oahe, and Fort Randall, a total of 11,800,000 acre feet has been reserved for sedimentation over the next 100 years. At the average cost of $9.13 per acre foot for the total storage in these reservoirs, the added cost for sediment alone is $107,000,000. But this sediment storage cost is the cheapest per acre foot in the Basin. Sediment storage of 260,000 acre feet to last 50 years in Boysen Reservoir on the Big Horn River is costing $19.60 per acre foot a total of $5,000,000. Sediment storage of 200,000 acre-feet in Harlan County Reservoir on the Republican River is costing $58.60 per acre foot, a total of $11,740,000. Costs in other smaller reservoirs are even higher.

Viewed in this perspective it is obvious that sediment in the Missouri River and its tributaries is, in fact, very costly to the tax payers.

But now that these 35 reservoirs, which will provide more than three-fourths of the eventual storage now contemplated in the Missouri Basin, are either completed or under construction, need we be concerned further about the sediment problem in this generation?

I think we must answer this question affirmatively.

Necessity of Preserving Reservoirs

Most of the storage being developed in the Missouri Basin is irreplaceable because there are no substitute reservoir sites that will provide the same services. I submit, therefore, that the economics of private enterprise—amortizing the investment at a given interest rate, however low, over a period of 50 or 100 years does not apply to this kind of development. These irreplaceable natural resources—the reservoir sites of the Missouri Basin—cannot be amortized. Nor can their exploitation be justified to serve only this generation and the next. The government of all the people in this generation cannot with conscience discount the heritage of their grandchildren ten times removed. Therefore, as a matter of public policy, the Government should immediately take all necessary steps to assure the minimum impairment of these natural resources that it is now exploiting. This

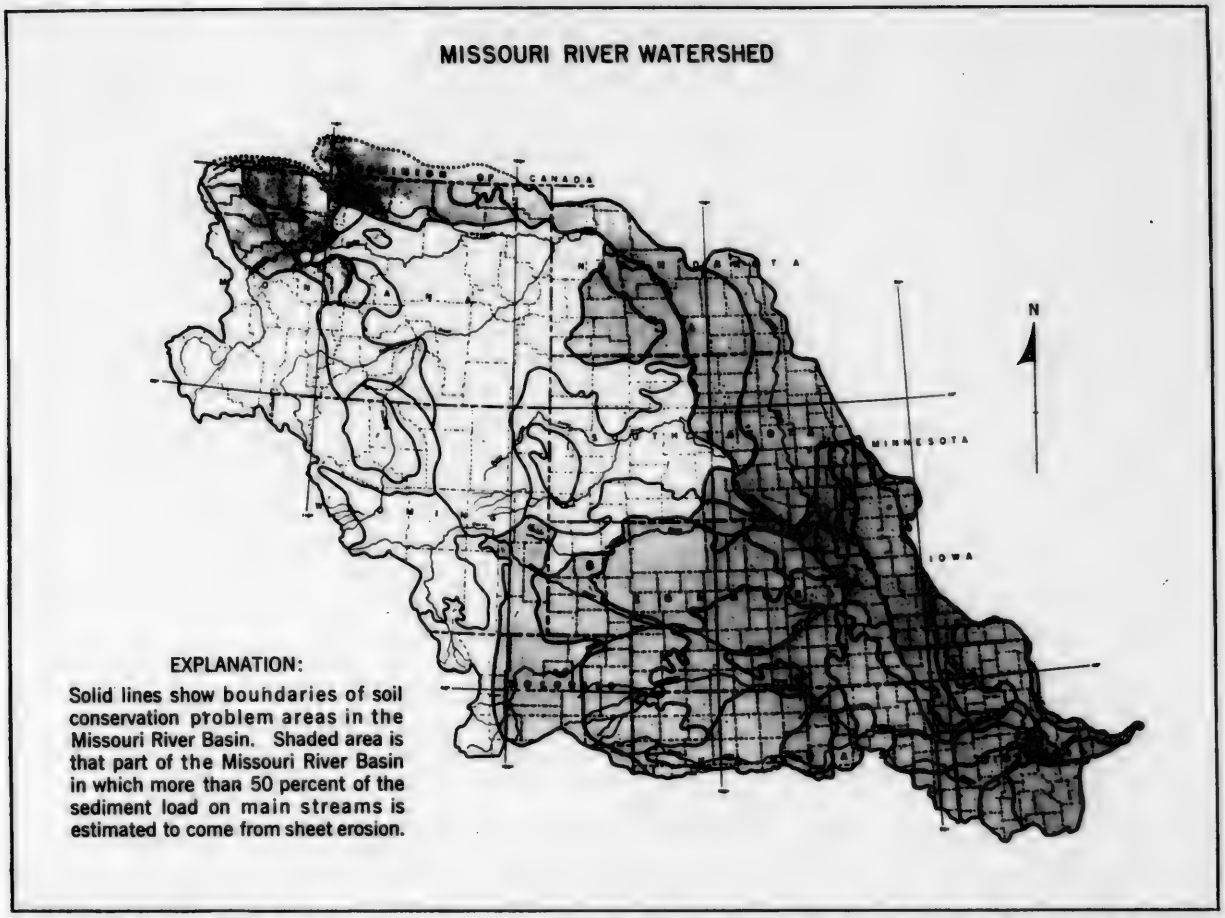

MISSOURI RIVER WATERSHED
CANADA
MINNESOTA
IOWA
N
EXPLANATION:
Solid lines show boundaries of soil conservation problem areas in the Missouri River Basin. Shaded area is that part of the Missouri River Basin in which more than 50 percent of the sediment load on main streams is estimated to come from sheet erosion.

Figure 2. This map indicates a wide range in sediment sources between the 36 major physical soil conservation problem areas in the Missouri River Basin.

might be accomplished by scheduling their exploitation in such a way that the admittedly large cost of soil and water conservation work can be borne concurrently with the other costs of basin development.

From a more technical standpoint it can be shown that under current conditions the actual service value of some Missouri Basin reservoirs will decline during the first 50 years despite the allowance made for sediment. More than half of the sediment, on an average, will be deposited in the active storage area, reducing the capacity for water that could in some cases perform a service under extreme conditions of drought or flood. Moreover, silting tends to increase the surface area of water per unit in storage and hence increases evaporation losses, which is a serious factor in the more arid parts of the Basin. Also it adversely affects recreation, fish and wildlife and other values.

Sources of Sediment

Substantial reduction of storage loss in large reservoirs can be achieved only by the reduction of sediment production in reservoir watersheds. What needs to be done and what it will cost depends largely on where and how the sediment originates.

The five principal sources of sediment in the Missouri Basin, (1) sheet erosion (2) gully erosion (3) badland and related geological erosion (4) alluvial valley trenching and (5) stream bank erosion, require markedly different kinds of control measures. Geologically, there has always been some sheet and gully erosion, locally severe badland erosion, and extensive stream bank erosion. The Missouri River has been known as the "Big Muddy" since the days of the earliest explorers. There is considerable reason to believe, however, that its sediment load today may exceed that of 100 years ago by an appreciable margin. But more important is the evidence that indicates its sediment load could be reduced over the next 30 years, not just to its "geologic norm," but substantially below that norm by a combination of proper land use and treatment plus extensive channel stabilization and sediment detention measures.

Studies made in connection with the United States

Department of Agriculture flood control activities in the Missouri River Basin indicate a wide range in sediment sources between the 36 major physical land units or soil conservation problem areas of the Basin. (See figure 2.) This map distinguishes that part of the Basin in which sheet erosion contributes generally more than 50 percent of the stream load from that part in which it contributes less than 50 percent.

For example, recent investigations of the Department of the Interior on the watershed above Boysen Dam on the Big Horn River, Wyoming, have shown that 40 percent of the sediment reaching Boysen Reservoir comes from Five Mile Creek, a tributary draining only five percent of the 8000 square mile watershed. Within this tributary 90 percent of the sediment was found to be coming from erosion of the main channel of Five Mile Creek as a result, primarily, of return flow of 100,000 acre feet of drainage water off of the Riverton irrigation project through a channel that originally had an average annual flow of only 3000 acre feet. In other words, 36 percent of the total sediment from the 8000 square mile watershed is coming from a single channel as a result of improper irrigation practices.

At the other extreme are conditions in the intensively cultivated eastern Dakota glaciated plains where gully and stream bank erosion are negligible and sheet erosion is the source of an estimated 97 percent of the total sediment load.

To substantially reduce the sediment load reaching Boysen Dam it will be necessary to carefully regulate water use for irrigation, and install expensive channel stabilization measures on Five Mile Creek. In the glaciated Plains, on the other hand, the land use and treatment practices, recommended by the soil conservation districts of that area can be expected, when they are fully applied and maintained over the entire area, to reduce sediment loads some 75 to 90 percent. Requirements for sediment control in most of the Missouri Basin are intermediate between these extremes.

Requirements for Sediment Control

Insofar as reducing sedimentation is concerned, the principal deficiency in current soil and water conservation programs is the lack of adequate gully and channel stabilization. Wherever gullies and valley trenches exist, their control is a key to the reduction of sediment reaching downstream reservoirs. This is true in many cases not primarily because of the sediment they yield directly but because they provide the flumes through which sheet-eroded soil material is delivered to main stream channels and because their headward growth and enlargement if unchecked make it impossible to permanently maintain the conservation practices applied on the land.

To overcome this deficiency, the Missouri River Basin Agricultural Program recommended to the Congress by the Secretary of Agriculture in September 1949 (H. Doc. 373, 81st Cong., 1st sess.) included measures for stabilizing small watercourses estimated to cost, at 1947 prices, $1.6 billion of which $1 billion was recommended for Federal expenditure. These measures included approximately 15,000 upstream floodwater retarding and sediment retention structures, 5000 miles of floodways, 11,000 miles of channel improvement and stabilization, 750,000 gully stabilizing and sediment-control structures, 190,000 miles of subwatershed waterway improvements and 65,000 miles of diversion ditches and dikes. The Secretary also recommended an acceleration of going conservation programs concurrently with authorization and appropriation for flood and sediment control measures so that the whole job of watershed treatment could be completed in 30 years at an average annual Federal cost of about $100,000,000.

It has been estimated that the Department's program would reduce sediment loads reaching downstream reservoirs an average of 50 percent, varying by soil conservation problem areas from a minimum of 36 percent to a maximum of 74 percent. I believe these figures are conservative. The principal remaining source of sediment that would not be controlled by the Department's program is streambank erosion along larger streams above the major reservoirs. They will probably have to be stabilized eventually, but the cost will be high. The Corps of Engineers has estimated, for example, that stabilization of the 760-mile reach of the Missouri River from Sioux City to the mouth will cost $218 million or $22,000 per mile. This is in addition to the $150 million already spent in stabilizing works on this section of the river.

The costs for watershed treatment and sediment control may seem staggering even in these days of multi-billion dollar budgets. But let us take a second look. The cost of the Department's accelerated land treatment program, for which no additional authority but only funds are needed, will be paid for several times over in benefits to the landowners and operators on whose land it is installed. Not a cent of this cost needs to be charged against downstream benefits. The stabilization of small watercourses, for which authority and funds are sought under Flood Control legislation, is estimated to have a benefit-cost ratio of 1.96 to 1. Approximately two-thirds of the benefits of this work are estimated to be on-site, however, in that these measures will permit the application and maintenance of land treatment measures that would not otherwise be possible.

Only a little more than one-half billion dollars must be justified by the downstream benefits in floodwater, sediment and land damage reduction. This does not seem unduly high as an additional cost for doubling the life, on an average, of the $4.5 billion Pick-Sloan plan development, not to mention the much larger flood and sediment control benefits upstream from the major reservoirs and levees.

Need for Watershed Planning

Watershed planning is the key to translating this concept of sediment control into reality with the greatest effectiveness in the shortest time at the least cost. The elements of this process are as follows:

First, the major hydrologic controls of the drainage basin should be recognized. For example, the watershed above each of the 150 major reservoirs of the Missouri Basin is a natural control unit because each reservoir will eliminate practically all physical effects of its watershed on the area below the dam.

Second, these major hydrologic control units should be divided into subwatershed planning units. This subdivision should be based on a watershed study of sources of excess runoff and sediment production in relation to the downstream problems which they cause. This is essential to determining the priority of treatment needs. Such a study above Boysen Reservoir has already shown that Five Mile Creek, a subwatershed containing five percent of the total area, causes 40 percent of the reservoir damage and the channel alone 36 percent. It should obviously have No. 1 priority for treatment in this hydrologic unit.

Third, a plan of treatment should be prepared. The kinds of treatment required should be determined for the subwatershed unit. In relatively small subwatersheds, a single plan may be made for the whole area. However, if subwatersheds are large and costs indicate that treatment would extend over a period of years, or if planning with local landowners and operators would be facilitated, the subwatersned may be broken down into minor watersheds. The plan for the subwatershed, or minor watershed, should include determination of the types, locations, costs and benefits for those water and sediment control measures that are not ordinarily included in conservation farming, range or woodland management. The subwatershed plan should be based on the assumption that all farm, ranch and woodland treatment measures will be applied through going soil and water conservation programs, primarily those of the 2275 organized soil conservation districts which now include more than 80 percent of the farmland of the Nation. Subwatershed planning would be concerned

Figure 3. An aerial view of Medicine Creek Dam looking northwest. The view compares favorably with the artist's conception of the completed dam.

mainly, therefore, with the additional measures needed, such as major gully control, stream bank stabilization, and others of the type recommended under stabilization of small watercourses in the Missouri Basin Agricultural Plan.

Fourth, farm, ranch, and forest land planning and treatment should be carried out within the framework of subwatershed plans by accelerating the going soil and water conservation programs that are based on the principles that every acre should be used within its capability and treated according to its needs as determined by scientific surveys of each farm, ranch or other ownership unit.

Obviously this approach is more complex and will require greater effort than present procedures in farm planning, in education, and in developing cooperation between individual landowners and operators. But it is the kind of approach that will, in the long run, result in the most effective total soil and water conservation per unit of cost and time.

The outstanding nationwide accomplishments in soil conservation to date have, perhaps, been due primarily to two factors: (1) the developing mores of an informed citizenry which has led, among other things, to the organization by landowners and operators of locally-controlled soil conservation districts as a means of accomplishing a job and (2) the availability of technical skill that has provided the landowner with a scientifically-designed plan for his whole farm or ranch and assistance in carrying it out.

But the current soil and water conservation programs, for all their rapid strides, still have their weaknesses. They tend to deal too exclusively with individual landowners, too lightly with community groups, urban people, and industries. They are rooted too firmly to property and political boundaries, too loosely if at all, to the only land boundaries nature knows—namely, watershed boundaries. The remarkable accomplishments to date have been more in the direction of keeping the good agricultural land good than in controlling erosion and excess runoff wherever they occur within the watersheds of the Nation. The best agricultural land is not the principal source of downstream problems in many large areas, including much of the Missouri River Basin. Rather it is the submarginal cropland and depleted range, the cutover and burned forest, the lands already gullied, the semi-arid sections and a few areas of rapid geologic erosion.

Watershed planning and treatment have already been accomplished in enough areas to have demonstrated that river basin developments can be safeguarded. In the watershed approach the treatment needs of each farm and ranch can be determined in the light of total community needs. Individual farm and ranch plans can be made within the framework of sound technical watershed plans. Land use and treatment needs can be related not only to the best interests of the individual landowner but also of his neighbors, whether they live in the next section, in the valley below, or many miles downstream.

Operations in the eleven watersheds authorized for Flood Control work by the Department of Agriculture and a few other watersheds where local interests have acted for self-protection are already providing the pilot plants and testing grounds for watershed treatment. The results are highly encouraging. They are giving many conservationists greater faith than ever before that the water resources of our river basins can be maintained in addition to keeping the good land good.

Terrace Drainage of Almena Soils

(*Continued from page* 74)

field was terraced to study the effect of terrace interval. On this field yields were decreased when the terrace interval exceeded 200 feet. This is another field indication that the major benefits of terracing derive from increasing surface drainage.

Results for 1950 show an average first year hay yield of 4100 lbs. dry matter per acre on the unterraced land and 5300 lbs. dry matter per acre on the terraced land—an increase of 28.6 per cent through drainage. Average yield from the terraced check (no fertilizer) was 4500 lbs. per acre while the average yield from the unterraced, 500 lb. per acre fertility level was 4300 lbs. Thus, drainage improvements alone yielded benefits during 1950 equivalent to a fertilizer application of 500 lbs. of 0-12-36 per acre.

Summary

1. Poorly drained soils of the Spencer Catena, principally Almena silt loam, comprise 4300 square miles in Central Wisconsin. Fields in the area have slopes from 0 to 4 per cent. The wet soils in surface basins and at the wet, lower portions of slopes delay seeding, mire machinery, reduce crop yields, drown seedings, and hinder harvesting (in wet fall season).
2. Observations indicate that internal drainage of these soils is insignificant and natural surface drainage is dependent upon local topography. Previous attempts to drain the soils include tile drains, bedding, large interception ditches, and ridge type terraces; all of which have failed to provide adequate drainage.
3. A drainage system including channel type terracing and land leveling has been designed to meet the drainage requirements of the area and has been inexpensively constructed ($7.00 to $17.00 per acre).

(*Continued on page* 100)

Recent Research Reviews

JAMES H. STALLINGS

The Reviews by J. H. Stallings that follow are a regular feature in the JOURNAL. It is hoped that the projects reviewed from time to time will be helpful to conservationists everywhere. Members of the Society are urged to indicate their interest in the kind of research work that should be reviewed.

A Practical Method of Determining Proper Lengths of Runs, Sizes of Furrow Streams and Spacing of Furrows on Irrigated Lands. *By* WAYNE D. CRIDDLE; *USDA-SCS. Multilithed. August 1949.*

The author describes a method by which the man in the field, even though of limited irrigation experience and possessing a minimum of equipment, may make a few simple tests, analyze the results, and use them effectively in laying out farm irrigation systems.

Nutrient Deficiencies Diagnosed With Foliar Analyses and Plant Tissue Tests. *By* J. A. LUND, L. M. TURK, and R. L. COOK; *Agron. Jour. Vol. 42, No. 8, pp. 402-407. August 1950.*

Results obtained in tissue tests reflected soil fertilizer treatments of nitrogen, phosphorus, and potassium on soil types differing widely in physical and chemical characteristics. A method for determining weak acid soluble manganese in fresh tissue was found to give a good indication of the total manganese present in the foliage of white bean plants. The third functioning basal leaf of corn plants, as used in the tissue tests and foliar analyses, was found to be a reliable indicator of fertilizer treatment. Periodic foliar analyses of corn plants indicated that plants change in composition as the season progresses.

Solving the Drainage Problems in Barrier Areas. *By* GEORGE B. BRADSHAW *and* WILLIAM W. DONNAN; *Paper presented at meeting of the Amer. Soc. of Agri. Engineers, Salt Lake City, Utah. March 1950.*

Drainage problems in irrigated areas generally occur where a barrier of heavy textured soil impedes the movement of excess irrigation water or seepage. There are two types of soil barriers which cause the water table problems. The most spectacular type of barrier often encountered in the flat irrigated valleys of the West can best be described as a long transverse subsurface dike or clay bar which lies at right angles to the general direction of subsurface seepage flow. The second and most common type of barrier is a layer or stratum of soil which underlies an entire area and prevents the natural release of ground water downward and out of the root zone of plan growth. Each of these types presents a problem in drainage design. The discussion herewith describes both of these barrier types and how the design problem on them has been solved.

A Recording Soil Pentrometer. *By* L. S. ROBERTSON *and* C. M. HANSEN; *Mich. Agr. Exp. Sta. Quarterly Bul., Vol. 33, No. 1, pp. 1-4. August 1950.*

The soil pentrometer described herein is mechanically actuated. The pressure required to force the probe into a soil is recorded on the abcissa of a graph. The depth to which the probe penetrates a soil is recorded on the ordinate. The force is theoretically one component, that of compressing a given calibrated coil spring. Owing to the fact that a coil spring performs a straight line function, a graph can be drawn. The ordinate of the graph is obtained from the action of a rod attached to a pad which rests on the surface of the soil.

The Dynamic Concept of Sediment Sources. *By* GUNNAR N. BRUNE; *Trans. Amer. Geo. Union, Vol. 31, No. 4, pp. 587-594. August 1950.*

Using 200 upland sample areas and 23 valley cross-sections, a study was made of rates of sediment production and sediment sources from the headwaters of the Sangamon River of Illinois to its mouth. It was found that as the size of drainage area increases, the upland sources of sediment, such as sheet and gully erosion, become less important, while the bottomland sources, such as streambank erosion, floodplain scour, and valley trenching, become constantly more important. The writer maintains that this dynamic concept of changing sediment sources with changing size of drainage area applies not only to the Sangamon River Watershed, but to any watershed.

It was also found that the annual rate of sediment production in the Sangamon watershed decreases from an average of 2,940 tons/sq. mil. of drainage area in the headwaters to 746 tons/sq. mi. at the mouth. This agrees with previous studies by the writer, which show that generally rates of sediment production decrease with increasing size of drainage area, for reasons which are set forth in the text.

The dynamic concept of sediment sources is compared with the previously widely used static concept based upon total erosion figures in a watershed, and the errors involved in the older concept exposed.

One of the more important conclusions drawn from this study is that streambank and other forms of bottomland erosion have not been given enough attention by

the various agencies concerned with their control, in comparison with their importance when viewed in the light of the dynamic concept.

Grassland Farming Increases Need for Potash Conservation. *By* MYRON A. BACHTELL; *Ohio Agr. Exp. Sta. Farm and Home Research, Vol. 35, No. 265, pp. 51-53. July-August 1950.*

High yielding meadow crops require more potash than large grain crops. When the farm program on highly fertile soil is changed to permit keeping a larger proportion of the land in high yielding grass crops, there is a considerable increase in the total amount of potash involved in this revamped program. The really big increase, however, is where successful shifting has been made possible by the use of limestone and phosphate. In many cases these have raised soils of low productivity to levels which permit from 3 to 5 tons of hay per acre.

Emphasis thus must be placed on the fact that more potash is involved in grassland farming than in grain production.

Erosion of Topsoil Reduces Productivity. *By* J. H. STALLINGS; *USDA-SCS-TP-98. August 1950.*

The potential increase in agricultural output resulting from the vast improvements made in the science of crop production in past years has been offset in large measures by the damage to the soil resulting from the action of wind and water in the erosion process. The sifting and sorting action of wind and water separates the organic matter and silt and clay fractions from the soil mass and carries them from the field. The parts lost contain most of the essential plant nutrients and other life-giving substances.

Large quantities of these valuable materials may be removed from a field by the erosion process without entailing a corresponding loss of soil volume from the surface of the land. In extreme cases the soil is removed bodily. These life-giving substances usually constitute the first portion of the soil to be removed by erosion.

Water Situation in the United States

(*Continued from page 82*)

period has been selected by the Geological Survey as a basis for computing normals of stream flow. As time goes on and stream-flow records lengthen, the base period will be extended to include more years of record. When the base period is extended, some figures of normal will doubtless be raised and others lowered. It may eventually be found that some of the normals based on the 25-year period are not truly representative of a longer period of years. For example, the apparent high incidence of years of below-normal stream flow in the Southwest may later be accounted for—at least in part—by the fact that the normals as now computed are too high. The converse may also be true in areas where there is now an apparent high incidence of years of above-normal stream flow.

On the basis of the 1921-45 mean, stream flow during the 1950 water year was excessive over a broad region extending from the Great Lakes to the Gulf of Mexico, in the Dakotas-Minnesota area, and in part of the Pacific Northwest. The spring floods in the Dakotas and Minnesota, particularly in the Red River of the North Basin, were the greatest in more than 50 years at some places. The largest area of deficient runoff was in the Southwest, where stream flow has been below normal during most of the years since 1945. Runoff was deficient also in most of the east coast region north of New Jersey. The critical water-supply shortage in New York City was alleviated by substantial spring runoff.

In the United States as a whole, runoff during the water year was deficient in only 14 percent of the area, whereas it was excessive in 31 percent of the area, a substantially greater percentage than usual. On the basis of areal extent, the wettest year since 1910 was 1916, when runoff was excessive in 90 percent of the Nation. The real extent of major droughts is generally much greater than that of major floods.

The runoff of the Ohio, Missouri, and Columbia Rivers during the water year was well above normal. The runoff of St. Lawrence River below Lake Ontario was only 9 percent above normal, and slightly less than in 1949, despite the fact that runoff into the Great Lakes was substantially greater in 1950 than in 1949. Much of the increase in runoff into the Great Lakes during 1950 remained in storage, as lake stages averaged about

(*Continued on page 106*)

Terrace Drainage of Almena Soils

(*Continued from page 98*)

4. The channel type terracing and land leveling drainage program was initiated in 1948 on very poorly drained to moderately well drained land. In all trials the drainage system proved beneficial to corn, small grain, and forage production where cultivation was practiced parallel to the terraces (across the slope). The cropping or production differences due to tillage direction in the terrace system on poorly drained sites is insignificant.
5. Drainage improvements and a suitable fertility program are mutually essential for maximum crop production.

LITERATURE CITED

1. Wojta, A. J., The Development and Study of the Channel Type Terrace. Agric. Eng. (Vol. 31, No. 5, pp. 227-229-251-253, May, 1950).

Book Reviews

PRACTICAL GRASSLAND MANAGEMENT. *By* B. W. Allred. *Sheep and Goat Raiser. San Angelo, Texas. 307 pages. $5.00.*

Farm and ranch planners will find much valuable reference material included in this publication. The author, "Bill" Allred, writing from a background of more than 20 years' experience and a large number of references, has set forth in popular style the background of grass agriculture, the rational use of grasslands, and some of the "know how" required in applying sound grazing practices. Nine of the 15 chapters deal with grass itself—its importance, use, health, and kinds of grasses. A short chapter is devoted to noxious grasses, or grasses of the Southern Great Plains that are injurious to animals that graze them. A chapter is devoted to the profitableness of grassland conservation. The use and importance of salt and water as grazing distribution factors is discussed. An outline of the steps required in developing a sound grazing plan is included.

An illustration of the four range conditions, recommended seeding practices for depleted grazing lands, and a list of the more common range plants for the grasslands of the Southern Great Plains are included.

References are cited on plant ecology, botany, range and pasture management, range and pasture seeding, plant nutrition, and selected glossaries, and a brief range glossary of range terms are included ahead of the index. The table of contents in front of the volume with the index in the back make it possible to quickly locate subjects or names mentioned or discussed in the text.

The volume has a number of very fine illustrations that add to the clarity and understanding of the text. Three reproductions of Frederic Remington paintings, and one of a Charles M. Russel painting should be of interest to collectors of both Remington's and Russel's material.

The book should be a good reference for both ranchers and college students of the Texas-Oklahoma area. Many of the principles described will be of interest to range technicians throughout the west.

—W. T. White, *Portland, Oregon*

WILDLIFE MANAGEMENT. *By* Ira N. Gabrielson. *The Macmillan Co., New York. 1951. xii + 274 pp. Illustrated with forty black and white photographs, and numerous tables. $4.50.*

As a former director of the United States Fish and Wildlife Service and now president of the Wildlife Management Institute, Ira Gabrielson is well known in conservation circles. The book brings his realistic philosophy into focus on the myriad and difficult problems facing wildlife managers today. Although this reviewer finds that Gabrielson leans to the "positivist" side as a scientist, nevertheless he has become the link between the old-line warden type of wildlife manager and the modern operational ecologist. (For a discussion bearing on this viewpoint, the reader is referred to Laura Thompson's "Operational Anthropology As An Emergent Discipline," *ETC. A Review of General Semantics,* Vol. VIII, No. 2, 1951, pp. 117-128.) Dr. Gabrielson has done well in bringing forward somewhat the view that wildlife managers today require the use of a "multi-discipline methodology" and the "substitution of predominately ecological and cultural approaches for predominately academic or engineering approaches." (Quotes are from Laura Thompson.)

The major objectives of wildlife management as they are set forth by Dr. Gabrielson are: (1) Preservation of species; (2) Maintenance of populations of useful species; (3) Stabilizing or decreasing populations of certain species; and (4) Limiting utilization to annual productive capacity. *"Sound conservation,"* he writes, *"is good sense—nothing more nor less."*

The need for "primitive" or "wilderness" areas to help preserve certain wilderness species and to furnish operational ecologists with "norms" was not discussed in *Wildlife Management,* but the writer states, *"Man should be reluctant to destroy that which he cannot possibly restore no matter how desperate the need."*

Although the work of the United States Fish and Wildlife Service was well presented, it seemed to this reviewer that the writer neglected the work of many biologists in the United States Soil Conservation Service, as well as the National Park Service and the Forest Service. Surely the land capability classification system and its implications in wildlife management should have been discussed. It seemed too that a much more useful index could have been made if the references to soil and moisture conservation programs had been included; they are in the text, and the writer attached much importance to the opportunities to wildlife management in the soil conservation districts (p. 189). Due to the organization of the material in *Wildlife Management,* a much better index seems necessary. Each reader will probably work out his own indexing.

In spite of some rather obvious omissions and a poor index, *Wildlife Management* is a worthwhile addition to the growing literature of operational ecology. *"Each year"* according to Dr. Gabrielson, *"the task of integrating the needs of fish and game with growing human utilization of land and water becomes more complicated. Better qualified leaders are needed. In fact, blundering leadership will cause more difficulties in the future than it has in the past."* In a generalized way, the writer has

listed for us most of the necessary lines of action which we now discern (1951) for managing wildlife. It has been no easy task to package these into 274 pages, and it means nothing *"unless the information obtained can be put into effect on the land."* Such an undertaking, states Dr. Gabrielson, *"is not even well started."*

—DOUGLAS WADE, *Princeton, N. J.*

HEDGING AND HEDGING PLANTS FOR THE SOUTH. By JOHN AFFLECK 1868. *Book is out of Print.*

My first discovery of John Affleck was in *"Grasses for the South"* from the 1849 Report of the (U.S.) Commissioner of Agriculture. I admired his vigorous style and extensive knowledge shown in this essay. My second discovery of him was in a series of his *"Southern Rural Almanac, Plantation Guide, and Garden Calendar"* for the years 1851-54. These are in a prized volume of the library at State College, Mississippi. I found again the same vigorous style and breadth of information. The almanacs contained directions for care of slaves, for growing cotton, corn, a vegetable garden, and starting a rose hedge fence. They also had advertisements of his nursery stock. Many varieties of pears, apples, peaches, roses, and rare shrubs and trees were offered. Rosa multiflora was one of them. The strain was evidently a climbing ornamental kind.

From the Dictionary of American Biography, I learned John Affleck had written a book on *"Hedging and Hedging Plants for the South."* I began a search for it. Herbert Hucks, Jr., Librarian at Wofford College, Spartanburg, S. C., finally located and borrowed a copy from Harvard University. It was marked gift of Charles Sprague Sargent. This small pocket-size book was written in 1868, the first of a proposed series by the author. Death prevented preparation of the others.

"Hedging and Hedging Plants for the South" is a unique summary of 27 years' observation and experience of establishing, maintaining, and utilizing hedges for fences. The favorite plants for fence hedging under average conditions were Cherokee and McCartney roses. A minimum fertility level equivalent to 30 bushels corn per acre was recognized. Well prepared soil maintained free of weeds was advised for starting the young plants. The long running stems were to be lifted by hand and interwoven into a narrow base hedge. This made an effective barrier for livestock and eliminated hiding places for vermin, i.e., birds, skunks, rats, rabbits, and snakes. Thousands of miles of these fence hedges were found on farms in southwest Mississippi during the 1850's. Lack of suitable timber for rails made hedge fences a necessity.

The book is enlivened with several "digressions." The story of the Cherokee rose in the United States is given in one, the effect of a severe winter near Charleston, S. C., in another, the loss of his own nursery stock in a burning steamship in a third, and a vivid word picture of a valley in south central Texas in a fourth.

The first cycle of rose hedge fences in the South ended with the introduction of barbwire. In the nine Southeastern States, apparently all fence hedges of Cherokee or McCartney roses, osage orange, Pyracantha, sour or bitter oranges, or any of the other plants advocated by Mr. Affleck, have been destroyed or have deteriorated. The McCartney rose has gone wild. It now occupies probably more than 100 thousand acres in east Texas, central Alabama, Mississippi, and South Carolina, being known as Cherokee rose in many places. No mention was made in *"Hedging and Hedging Plants for the South"* of its objectionable habit to take over idle land and open sod pastures.

The second cycle of hedge fences is now developing with the semi-erect Rosa multiflora and trifoliate orange as the favorite plants. The high cost of fence posts is one contributing cause. Protection to some "vermin" of a century ago is another. Can the experience of 100 years ago be useful today? I believe it may. Certainly fairly rich land, good preparation, and cultivation are necessary for good hedge fences. Will Rosa multiflora go wild? There is some evidence in central Alabama, northern Georgia and Virginia that it will spread by seed to non-cultivated farm land not fully occupied by thick sods or dense forests. The rate of spread is apparently slower than for McCartney rose or for native blackberries.

—PAUL TABOR, *Spartanburg, South Carolina*

FORAGE AND PASTURE CROPS. By W. A. WHEELER. *D. Van Nostrand Company, Toronto, New York, London. 1950. 752 pp. $8.00.*

This book is well timed. We are in the midst of important agricultural adjustments. Never before have so many farmers wanted information about grasses and legumes for forage, pasture, and soil-conserving ground cover.

Professional agricultural workers are called upon for a much greater variety of information than was the case a few years ago. Here in the South, most of the requests from farmers were about cash crops, fertilizers, insects, and livestock (particularly when animals were sick). About the only questions about grass were in connection with the eradication of Bermuda or other grasses that were cropland pests.

These conditions have changed. Farmers want new and better grasses and legumes. When they read in farm magazines about any new kinds, they want more infor-

mation. Often these new kinds are not adapted in the areas where the interested farmers live. Local professional workers usually have had no experience with them and sometimes are not in a position to give dependable information. They need a good reference book from which they can get information.

Forage and Pasture Crops gives a wealth of information about grasses, legumes, weeds, poisonous plants, insects, and diseases all in one handy volume. It is a good reference book for the library of any professional worker who wants to keep up with what is going on in the field of forage and pasture crops.

This book is remarkable in its scope. A careful check of our sectional plants here in the South shows that nearly all of them are included. A few of the newer and relatively untried grasses are not included, but, in the main, the author has done a remarkably fine job of covering the field.

The chapter on Green-Manure and Cover Crops gives a good picture of the situation in the different parts of the country. But even this new book will likely need revision within a few years to keep pace with developments in this field. Several of the reseeding legumes that are mentioned have come forward very rapidly during the past few years. Button clover and wild winter (Caley or Singletary) peas, for example, are being grown on an ever increasing acreage in the Southeast. The principal acreage of button clover has shifted from middle Tennessee to the Tennessee Valley section of northern Alabama. Caley peas are finding much wider usage as a reseeding legume on cultivated lands than was the case a few years ago.

The chapter on the Establishment and Management of Pastures gives the reader an opportunity to learn something about the pasture picture in other sections of the country. It also gives some of the important principles that apply everywhere. Land preparation, liming, fertilizing, and a good job of seeding have proved to be essential in getting pastures started and to keep them going. Phosphate is almost universally needed on the soils of the Southeast, and potash is proving to be essential for the maintenance of good stands of legumes on most soils.

In discussing pastures of the Southeast more emphasis might well have been placed on combinations of Coastal Bermuda and reseeding crimson clover or the Bahia grasses and reseeding crimson clover. These combinations are doing well enough on some of the farms in the Coastal Plain to justify a prediction that if this book is revised a few years hence these combinations will merit more attention.

The average professional agricultural worker should derive great benefit from reading the chapter on Improving Our Forage Crops. Most of us probably have not realized how much the plant breeders are doing to develop better strains of forage and pasture plants. Coastal Bermuda grass is an outstanding example of the benefits from grass breeding work in the Southeast. The reseeding crimson clovers, which have developed through natural selection on farms, are valuable additions to our Southern forage and pasture crops. Likewise, Kenland red clover should be extremely valuable as seed production is increased. We owe much to the breeder who develops better kinds or who finds improved species and brings them into use.

Insects, diseases, and weeds are always with us. Most of the important ones are described. Suggestions are made for control, or for management practices that help us to live with them. The use of lime and fertilizer to make desirable plants grow more vigorously and compete with weeds has proved to be good practice in the humid South. Mowing and grazing management also have been helpful.

I think the coverage of the important grasses and legumes is good. If the species that are adapted in other parts of the country are covered as thoroughly as are ours in the Southeast, the book is remarkably complete. I should have liked to have seen sericea lespedeza treated as a separate legume, on a par with several of the clovers and other legumes. This hardy, deep-rooted perennial has had a rough road to recognition. In areas where it has been used extensively it has caught on with farmers and their livestock.

I was glad to see hay and silage treated rather fully. Hay is an important by-product of good pasture management. This is particularly true where grass seed is produced. Even in areas with long growing seasons and high annual rainfall, we often need hay for short periods. Rough, coarse hay made after grass seed is harvested is valuable where beef cattle are pastured on lush, succulent stands of Ladino clover in the spring. Dry, coarse hay helps to reduce the danger of bloat when it is kept available in pasture. Dairy cows usually get enough dry feed at the barn to reduce danger of severe bloating.

Grass silage is a long step forward in a pasture and feed-production program, particularly on dairy farms. The excess grass that animals cannot eat during peak periods is going into silos to bridge the gap when pastures are short. The making of grass silage is well covered. I particularly like the part of the discussion on conditioners as against the popular idea that these materials are preservatives.

The seed information chapter at the back of the book

should be very useful to those of us who have short memories for figures. Such things as number of seed per pound, longevity of seed, acre rates of seeding, and regional adaptation given in the tables at the back will give us a convenient reference for information that we often need, but can't remember.

It is a remarkably good book that should occupy an important place in the libraries of professional agricultural workers and farmers.

R. Y. BAILEY, *Spartanburg, South Carolina*

L'HOMME ET LE SOL. *By* HENRI PRAT. *Librairie Gallimard, Paris. 1949.*

L'Home et le Sol (Man and Soil) was written by a Canadian university professor and published in France. It is number 22 in a series dealing with various phases of human geography being issued under the direction of Pierre Deffantaines. The book is, as the title indicates, a consideration of the relationships between man and soil.

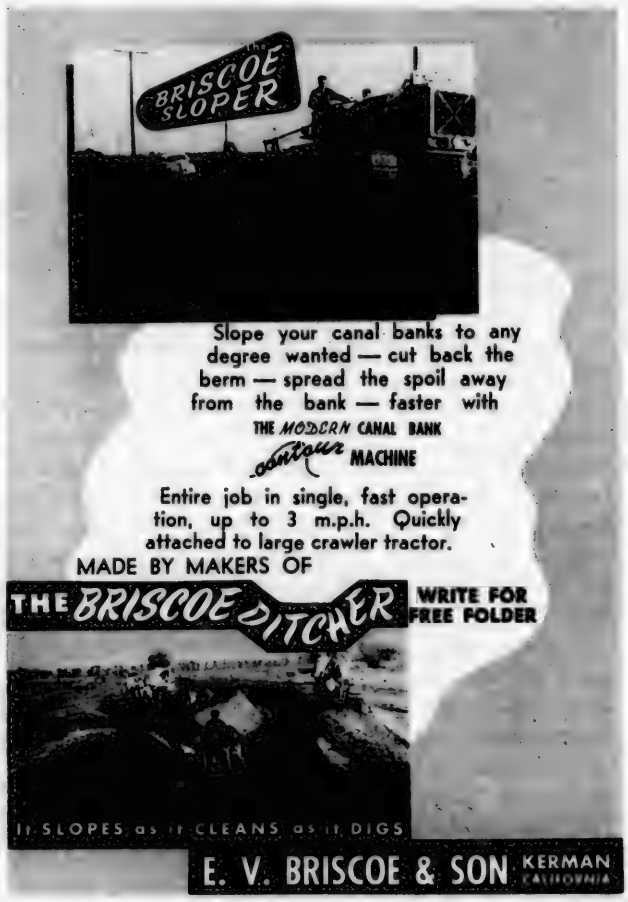
Much of the text is occupied with agriculture and its current problems in France in contrast to Canada and the United States of America, and with a retreatment, novel in many respects, of the distribution of soils of the world, the variations in agricultural techniques as man adapts them to the different climates, and to agricultural evolution. Considerable attention is given to the need for expansion of research and education in agriculture, particularly in France, but throughout the world, too, with the United States of America agricultural college and extension activities held up as an example to be emulated.

I think, however, that the most important contribution made by Prat concerns his conceptions of the unity of man with soil and the nature of soil, and the conservation needs of man as they are related to contemporary world affairs. Prat's re-examination of these vital questions represents a step forward in the unfolding of world consciousness of the true nature of man.

This dramatic construction of the man-soil relationship is much more powerful than the orthodox and weaker argument that "man is dependent upon soil." It is not enough to say merely that man is dependent upon soil. *Man is soil.* A man in an animated package of soil; his skin is a container which encloses marine-generated protoplasm that has come to him by way of soil. Man can nourish and sustain the life which his epidermis contains only by ingesting certain suitable combinations of soil-elements which are made available to him only by means of certain "biological transformers"—plants that have their roots in the soil-mantle in intimate unity with the microfloral, microfaunal, and inorganic soil elements. Looked at in another way, soil encompasses man.

It is obvious, therefore, that when man destroys soil he is destroying himself. He is destroying the only medium in which his "biological transformers" can operate.

Prat closes his discourse by calling attention to the need for a world organization for the utilization of soils —with ultimate famine as the alternative. "The brutal fact is this: the total population of the globe now exceeds two billion and increases each year by more than twenty million people. The resources do not increase at the same rate. . . . The extent of cultivation soils is diminishing instead of growing larger." In the face of limited resources, the growth of population appears illimitable—it will exceed four bililon before another century. To the oft repeated contention that technical progress will suffice he maintains that it is as yet applied only in restricted areas, its application to the whole world will not be possible until peace is established, and as long as people persist in organizing their economies for the


BRISCOE SLOPER
Slope your canal banks to any degree wanted — cut back the berm — spread the spoil away from the bank — faster with
THE MODERN CANAL BANK
Contour MACHINE
Entire job in single, fast operation, up to 3 m.p.h. Quickly attached to large crawler tractor.
MADE BY MAKERS OF
THE BRISCOE DITCHER
WRITE FOR FREE FOLDER
IT SLOPES as it CLEANS as it DIGS
E. V. BRISCOE & SON KERMAN CALIFORNIA

purpose of attack or defense, so long will the works of peaceful development occupy the place of lowest priority.

The author proposes a world inventory of soils, and world union for planning use of soils. He thinks we should turn attention from creation of new and more effective means of destruction (which in itself prolongs war) to a unified effort to develop the planet for benefit of people. The soil, docile and fertile, will open itself to nourish a happy humanity or to receive the broken fragments of fratricidal rage and will use the elements thus returned to it to produce new life. But perhaps the new life will be produced without benefit of human association.

This should not be dismissed as "neo-Malthusianism." It is an eloquent restatement of the argument for global planning, and for the early establishment of world economic and political reforms that will allow a total conservation movement to take place.

It is difficult to conceive of any justification strong enough to order another war at a time when the worlds dwindling resources can no longer support the world's population. Especially is this difficult in view of the new destructiveness of war, the probability that the war must, by the nature of the geography involved, be destructive rather than decisive.

War is the diametric antithesis of conservation. War is the waste of resources in the destruction of humanity; conservation is the careful husbanding and careful use of resources for the welfare of humanity. Man can save himself yet, but it will take a great deal of doing, and he should be getting at the job. "It is later than we think."

—PAUL PHILLIPS, *Grand Junction, Colorado*

Manual of Soil and Water Conservation Engineering. *By* GLENN O. SCHWAB, RICHARD K. FREVERT AND KENNETH K. BARNES. *Published by William C. Brown Company, Dubuque. Iowa. 222 pages. Spiral Wire Binding. Illustrated. 1950. $2.50.*

The Muskingum Story. *16-page illustrated pamphlet. Published by the American Forestry Association, Washington, D. C. 1951. 50 cents.*

Forest Management. *By* HERMAN H. CHAPMAN. *The Hildreth Press, Bristol, Connecticut. 1950. 582 pages.*

Conservation Education in American Schools. *American Association of School Administrators, 1201 Sixteenth Street, Northwest, Washington 6, D. C. 527 pages. $4.00.*

Proceedings of the United Nations Conference on Conservation and Utilization of Resources, *Volume 1, Plenary Meetings. Columbia University Press, 2960 Broadway, New York 27. 431 pages. 1950. $4.50.*

New Conservation Film

Steel Fingers and Green Thumbs. *Color with Sound. Running Length 30 Minutes. 1951. Harry Ferguson, Inc., 3639 E. Milwaukee, Detroit 11, Michigan.*

The theme of *"Steel Fingers and Green Thumbs"* centers around a typical farm family and their work in practicing good agricultural measures. Emphasis is placed on the important part the farmer and family play in the total economy and how totally mechanized farms benefit all people. Soil and water conservation measures, irrigation, and other farm practices are featured.

Neighbors of the Land. *Color and Sound. Produced by the Oliver Corporation, 400 West Madison Street, Chicago 6, Illinois.*

This full color film, produced by the Oliver Corporation, was developed to highlight the neighbor group approach to soil conservation. It was filmed in Seminary Township, Fayette County, Illinois. The farmers, upon whose land the film was taken, are the principal players in the production.

In Support of Soil Security...
NITRAGIN RESEARCH

The vigor and constancy with which the NITRAGIN Company promotes the value of legumes, and the importance of their inoculation, does much to further soil conservation and better farming practice. The NITRAGIN laboratories are the largest and most complete in America devoted exclusively to the production and testing of legume bacteria. If you have an inoculation problem or are conducting experiments that require special bacterial strains, write us about your work. We will be pleased to cooperate with you.

THE NITRAGIN CO., INC.
3936 N. Booth Street, Milwaukee 12, Wis.

Water Situation in the United States

(*Continued from page* 100)

0.8 foot higher than a year ago. The runoff of Colorado River was below normal, even though the flow of Green River, one of its major tributaries, was above normal.

Reservoir storage as of September 30, 1950, was generally at or above the average of record for September 30, with the exception of irrigation reservoirs in the West, the aggregate storage in which is below average. The most critical situation, as far as irrigation storage is concerned, exists in parts of Colorado. In California the situation is generally improved over a year ago, except in the southern part of the State.

The pattern of stream flow in relation to normal for the water year ending September 30, 1950, has continued through October with few changes. Runoff in the Pacific Northwest continued above normal, with record-breaking high average flows for October occurring in southwestern Oregon and northern California. The drought in the Southwest continued, with record-breaking low monthly flows occurring at several points in Arizona. Above-normal runoff continued in a wide area between Louisiana and Pennsylvania. Runoff in the coastal States north of New Jersey continued below normal.

We wish to emphasize that water is a renewable resource even though it does not always renew itself in the same place. If Adam had measured all of the water on earth at his time, and if we measured all of the water today, there probably would be little difference in the two totals. As a matter of fact, the water we drink today may have been Cleopatra's bath-water yesterday. However, regardless of the source, rain and snow fall on our land, in ever variable patterns, but in aggregate amounts that we believe are substanutially the same as when Christopher Columbus first touched these shores. But it is up to us to make planned—not haphazard—use of what we have.

LITERATURE CITED

1. Freeman, Otis S., "Evidence of Prolonged Drought on the Columbia River Plateau Prior to White Settlement," Monthly Weather Review, Col. 57, 1929, p. 251.
2. Harding, E. T., "Variations in Runoff of California Streams," Civil Engineering, February 1935, Pp. 87-90.
Harding, S. T., "Changes in Lake Levels in Great Basin Area," Civil Engineering, September 1935, Pp. 572-574.

What Determines Value of Water

(*Continued from page* 91)

the water was allowed to flood at random from the meandering stream channel over uneven ground during the high water period in the spring and it was diverted at intervals by brush dams during the low water flow in early summer. Willows grow prolifically along the stream banks and ultimately took up 30-40 percent of the area as well as much of the water.

The return from the original ranches was low because the ground was uneven, the distribution of water variable, and the plant species low in nutrient value. The value of water in this operation was, therefore, low.

The present owners of this land and water decided to change the management practices. Diversion canals were built to take all of the water out of the original stream channels. The land was cleared of willows and leveled for border irrigation. The available water supply was spread over more ground. The irrigation applications were more uniform. The ground water table was controlled and a part of the natural flow put into storage reservoirs for use in late summer. Figure 1 shows a panoramic view of the Mitcham Unit before the removal of willows and leveling the land. Figure 2 shows removal of willows and construction of drainage ditch. Figure 3 shows 200 acres of the land being leveled in one block. This better management, land leveling, better varieties of grass, all contribute to increase the yield. Water is the limiting factor. Therefore, the value of the water after development is many times its value before development.

The principles applied to establish the value of water for agricultural purposes cannot always be used to establish the value of water used for other purposes. In general, however, the value of the benefits derived from a water development may be used to indicate at least the minimum value of the water.

Theoretically, a water development project is justified economically if the benefits accruing therefrom exceeds the cost thereof. In other words, the benefits-cost ratio should be greater than unity. If it were unity, the cost would represent the value. If it were greater than unity, the value would be greater than the cost.

The State of California suggests that (6) the value or benefit resulting from water development should be based on the following general principles:

1. *Domestic, Municipal and Industrial Water.* Benefits should be revenues from sale of water at a price based on its vendibility.
2. *Irrigation.* Benefits should be limited to increase in net income resulting from water development.
3. *Hydroelectric Power.* Benefits should be limited to revenues derived from the sale of electric power.
4. *Navigation.* Benefits should be limited to savings in transportation costs over other means.
5. *Fish and Wildlife.* Benefits should be limited to the net effect of the water development on local business and recreational values.

People throughout the land are becoming water con-

(*Continued on page* 110)

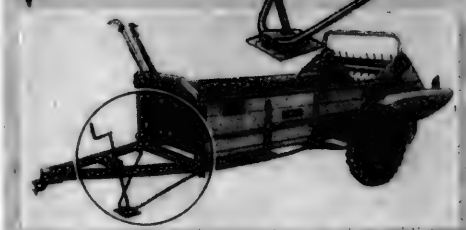
MINNEAPOLIS MOLINE
MM
MODERN MACHINERY

LS 300 SPREADER

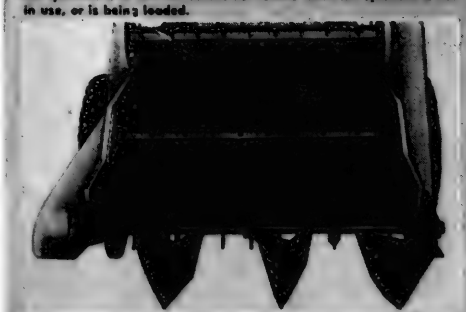
Larger Capacity
75-80 BUSHEL BOX
IS REINFORCED WITH STEEL

Spreader box quality constructed of wood with single steel angle frame. Bottom is of specially creosote-treated wood to prevent rot.

ALSO AVAILABLE AS A 4-WHEELER FOR HORSE OR TRACTOR POWER



A new patented Handi-Quick hitch screw jack enables you to hitch the LS 300 safely, easily, and quickly. The jack folds under the hitch when the spreader is in use and serves as a stand when the spreader is not in use, or is being loaded.



The LS 300 does a thorough job of shredding the manure to bits as there is no horizontal clearance between the upper and main beaters.

The dynamically designed feed cam of the LS 300 enables you to spread 3, 6, 9, 12, or 15 loads per acre. You get more value from the manure through more even distribution.

MANURE IS VALUABLE . . . USE IT WISELY WITH THE LS 300

The New Minneapolis-Moline LS 300 Spreader, a two-wheel tractor model, offers the modern farmer many advantages of the now famous Moline LS 200 plus these additional soil-saving, cost-reducing features:

Larger capacity of 75-80 bushels . . . Handi-Quick hitch screw jack for quick, easy hitching of spreader . . . jack also serves as a stand when the spreader is not in use . . . heavy-duty steel axle, 2 inches in diameter . . . dynamically designed three-lobe feed cam with large roller for smoother operation . . . five settings for regulating distribution of manure for approximately 3, 6, 9, 12, and 15 loads per acre . . . control levers are easily reached from the tractor seat . . . larger main beater for more thorough shredding action . . . flanged steel shields on the upper beater prevent wrapping of long manure . . . beater shafts are of 1¼ inch diameter to assure long life . . . spreader box constructed of wood on a heavy-duty frame, large steel angles for greater strength and for durable service in rough fields . . . balanced weight and disc wheels with 7.50 x 18 pneumatic tires for easier handling . . . smooth-acting, trouble-free roller chain to drive the distributor . . . box reinforced with heavy gusset plates . . . heavy-duty steel angles protect top of box from damage when using mechanical loader . . . headboard shield prevents corn cobs from getting under conveyor. Also available in 4-wheel tractor-drawn and horse-drawn models.

A new patented Handi-Quick hitch screw jack enables you to hitch the LS 300 safely, easily, and quickly. The jack folds under the hitch when the spreader is in use and serves as a stand when the spreader is not in use, or is being loaded.

Quality Control **IN MM FACTORIES ASSURES DEPENDABLE PERFORMANCE IN THE FIELD!**

SIMPLE POSITIVE DRIVE

One heavy-duty steel chain drives both beaters, assuring positive action with fewer wearing parts. Sturdy steel shields completely cover driving gears and steel chain. Any looseness of main drive chain is taken up automatically. Roller chain is used on the distributor drive to insure smooth operation at higher speeds.

MINNEAPOLIS-MOLINE
MINNEAPOLIS 1, MINNESOTA

FIELD NOTES AND COMMENTS

Izaak Walton League Founders Plaque Awarded to Dr. Bennett

Dr. Hugh H. Bennett, chief of the Soil Conservation Service and Founder of the Soil Conservation Society of America, has been awarded the Izaak Walton League of America founders' plaque as the person *"judged to have made the oustanding contribution to furthering the conservation of America's vital renewable resources"* during 1950.

The formal presentation of the coveted award was made at the League's annual national convention in Cincinnati, Ohio, on April 6 by Dr. Preston Bradley, a founder of the League and chairman of the award committee. In a formal notification signed by William Voigt, Jr., executive director, the IWLA wrote Dr. Bennett as follows:

"We had before us for consideration a full score of individuals and organizations. After weighing the accomplishments of all, we felt there was none more worthy of receiving the award this year than you, the acknowledged father of soil conservation in America. We are convinced that it is only through grass roots work such as is inherent in the soil conservation program as administered and advocated by Dr. Bennett, that we can maintain a self-reliant and prosperous democracy."

Dr. Bennett is the third recipient of the League's highest award. William Vogt, author of *"Road to Survival"* and Leslie A. Miller, former governor of Wyoming, chairman of the natural resources task force of the Hoover Commission, were honored in 1949 and 1950. The award itself is a handsome bronze plaque designed and sculptured by Louis Paul Jonas of Hudson, New York.

The New Reclamation Era Gets Under Way in Turkey

Some 55 per cent of the worlds land surface get less than 30 inches annual percipitation and it is poorly distributed. It is the mission of reclamationists to help free the land from flood and drought. Freedom from food and want throughout the world is an accepted goal of the United Nations which two or three decades of peaceful development could largely accomplish. Permanency of agriculture under irrigation requires avoidance of the mistakes of the past that caused decline of nations in the "cradle of Civilization" or the Near East. These include denudation—erosion, floods, drought, alkali, disease, destructive wars, and earthquake damage.

Turkey in the Near East is strategically located near the junction of three continental land masses. Some valleys there have been cropped perhaps 5000 years, for annual flooding and silt deposition mineral nutrients and the valley soils are calcareous and unleached. Reclamation there would help to supply needed food and textile materials and win dollar credit, while increasing markets. The United States now sells Turkey one-third her imports and buys one-fifth of her exports.

Three reclamation projects studied in Turkey the past two summers are multi-purpose and include flood control, hydro-electric power, irrigation, and major drainage. They are related in part to the ECA program, and carried on in cooperation with the Turkish Ministry of Public Works. The work included selection, irrigability land classification and land use capability studies as well as irrigation requirement analyses of 235,000 acres on the Gediz, 300,000 in Adana area, and 200,000 acres in the Big Meanders (Buyuk Meneres). Some irrigation (Figure 1) is now available for 105,000 acres in these three areas.

More than 1,000 Marshall Plan tractors are used in midsummer to drive centrifugal pumps of around 2 sec-ft. capacity.

The country rock contributing to the soil material includes limestone, gneiss, conglomerate, some sedimentary formations and basalt. The soils developed under a Mediterranean climate with moist winters and hot, dry summers. The alluvial valleys are mainly grayish-brown chestnut soils. The old terraces are mostly Mediterranean red earths. In cross section there is a sandy first bottom, then a bankland of loam to silty clay loam, a back slope of calcareous adobe, and a backbottom of black or very dark saline clay, then the terraces and fans of the foothills.

Vegetation and climate are similar to San Joaquin valleys. Cotton, figs, and grapes of the same varieties are grown and yields are comparable. Apricots and

Figure 1. A diversion dam in the Big Meanderes Valley, Turkey. Canals lead away on the right and left banks with a capacity of ten and six cubic meters per second respectively. (*Photo* by *W. L. Powers*).

Look at all these EXTRA FEATURES!

Yes, you can believe your own eyes . . . You can take a good look and *see* why Firestone Tires pull better and last longer.

Notice the bars. You'll see they're curved to cup and grip the soil for a firm, sure hold to eliminate slippage.

Examine the openings between the bars. See how they flare out at the shoulders to permit automatic soil release. You'll notice there's no "wedged-in" pinching nor bar-end soil cramping.

Look at the treads of these tires. Observe how wide, how flat they are for full traction contact, long, even tread life.

Only Firestone gives you all these extra features. Only Firestone gives you your choice of top quality in either Open Center or Traction Center design. So, before you buy, LOOK!

. . . ALWAYS BUY TRACTOR TIRES BUILT BY FIRESTONE, ORIGINATOR OF THE FIRST PRACTICAL PNEUMATIC TRACTOR TIRE

Listen to the Voice of Firestone on radio or television every Monday evening over NBC

Copyright, 1951, The Firestone Tire & Rubber Co.

Figure 2. Ameralen Canal below the diversion dam on the lower Gediz River, Turkey . (*Photo by W. L. Powers*).

olives are grown on the terraces as well as figs. Small grains, corn, Egyptian corn, beans, and sesame are grown after the land dries out on the flood plains without irrigation. With irrigation, cotton is the money crop. Straw, stalks, and even cowchips are removed for winter feed or fuel. The soils are low in available phosphate and organic matter rather generally. Yet in some irrigated gardens the soil has been changed from a grayish-brown to a black by organic manuring over the centuries.

Water control and irrigation will provide drought insurance, aid soil building with legumes, permit double cropping, aid soil preparation and early fall seeding, aid nitrification, and frost protection. Irrigation will double production on the average, and so create new farm opportunities. Intensive agriculture renders sufficient the least amount of land for the support of one family, a condition that makes for peace and security.

—W. L. POWERS, *Corvallis, Oregon*

Quebec Planning Grass-land Program for More Water

Light-textured soils, gravelly loam and sandy loam, cover approximately 40 per cent of the Appalachian plateau in the province of Quebec. The traditional four-year rotation, comprising two years of grain and two years of hay, has been very widely used in that region, with the result that most soils contain less than two per cent organic matter. Such a situation becomes particularly critical during the month of August when the rainfall does not generally exceed one inch. Then, the water supply becomes so low that permanent wilting occurs and reduces grain yield by approximately one fourth and pasture yield by one half for the rest of the season.

In order to rebuild organic matter in these light-textured soils, and thus prevent damages due to late summer drought, a vast program of grass-land farming is being initiated. Since alfalfa is the backbone of grass-land farming in North Eastern climates, a special attempt is being made through plant breeding and soil fertility work to intensify alfalfa culture.

—C. J. OUELLETTE, *Ste. Anne de la Pocatiere, Quebec.*

What Determines Value of Water

(*Continued from page* 106)

scious. They recognize the limit of the growth of this nation will be its water supply—already new sources of water supply are being considered. Research is being directed toward (1) cloud seeding, (2) making water potable, (3) salvaging sewage and industrial wastes, (4) transporting the Columbia River water to southern California, (5) artificially recharging underground aquifers. All of these methods of increasing water supplies will be extremely costly. In the end such costs may fix the market value of water but not the real value. This depends upon its use and conservation, and greater efficiency in its use greatly increases its value.

LITERATURE CITED

1. Report to the President's Water Policy Commission by the Utah State Agricultural College. Mimeographed 1950.
2. Factors That Give Value to Land or Basic Land Values, by Karl Harris, Soil Conservation Service. Bulletin 223. Arizona Agricultural Experiment Station. 1949.
3. Reclamation Era, August 1950. P. 152.
4. Value of Water for Irrigation in Salinas Valley, California, by P. A. Ewing, Soil Conservation Service. Mimeographed.
5. Permissible Annual Charges for Irrigation Water in the Upper San Joaquin Valley. Bulletin 34. Division of Water Resources. 1930.
6. Views of the State of California on Elements of a National Water Resources Policy, Submitted to the President's Water Resources Policy Commission. June 1950. Mimeographed.

"Before And After"

"Before and After" photographs taken by a conservationist usually show an eroded field or hillside in one scene, with a companion picture showing the same area after the damage has been corrected by appropriate conservation practices.

Figure 1, taken by the author in 1932, shows a lone oak tree in the midst of a devastated range area south of Monolith in the Tehachapi Mountains of California. At the time of this photograph the general area was heavily grazed for miles around and practically denuded of vegetation. Following a 7-inch rain, several square miles in this vicinity were ripped to pieces. At the headwaters of Caliente Creek, hundreds of rods of the main channel were washed out to a depth of from six to ten feet, roads disappeared, fences were buried, and the hillsides were laced with a myriad of gullies up to two feet and more in depth.

NEW!

Soil Conservation Color Film . . .

"Neighbors of the Land"

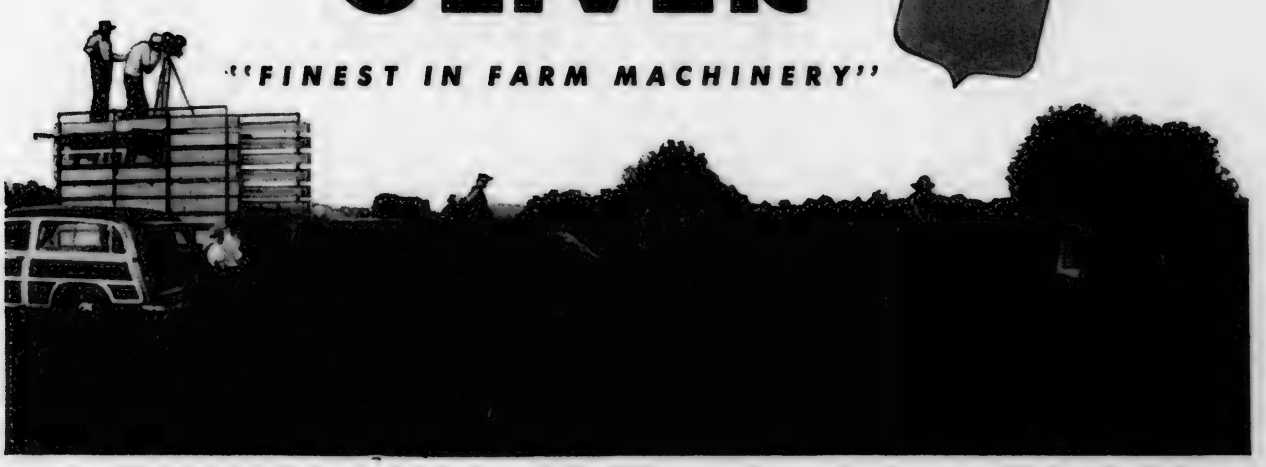
For the first time here's a documentary-type, informational film, dramatizing the creation, development and achievement of a typical *neighbor-group* soil conservation program. "Neighbors of the Land" is devoted expressly to conserving soil and water, and portrays what can be accomplished when neighbors work together.

Oliver films are loaned without charge to agricultural leaders and appropriate groups—county agents, extension workers, vocational agriculture teachers, soil conservationists, farm clubs and civic organizations. Schedule this new full color, 16 mm. sound movie through your neighborhood Oliver dealer or branch office, or write to The OLIVER Corporation, 400 West Madison Street, Chicago 6, Illinois.

OLIVER

THE OLIVER CORPORATION

"FINEST IN FARM MACHINERY"



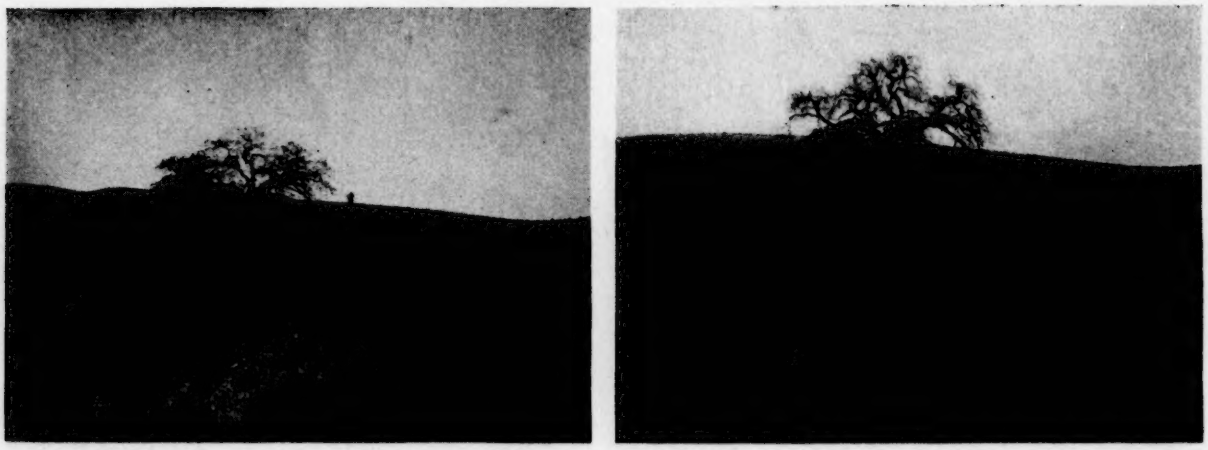


Figure 1—*Left*—A range area in the Tehachapi Mountains of California as it appeared in 1932. Much of the erosion resulting from a 7-inch rain might have been avoided had the area not been almost completely denuded of vegetation by many years of overgrazing. *Right*—The same area in 1949, seventeen years later. With the gullies gone and a sparse stand of vegetation creeping back, the area appears to be greatly improved. Actually, it is much worse. A foot or more of the top soil has disappeared and it will be decades before the area can again support a satisfactory stand of vegetation.

An interesting example of the effect of litter is indicated by the complete lack of gullies under the tree itself. Although the slope was gullied on both sides of the tree, above, and below, there was no erosion under the tree itself. There the foot or so of twigs and litter beneath the crown stopped the gullies from above, and held the soil in place.

The "after" photograph was taken in 1949, seventeen years later. To the inexperienced observer the area probably appears greatly improved. There is now little active soil movement. Too, the corners of the larger gullies are rounded off, and the ground surface is partially protected with a sparse stand of vegetation. Most of the plants are annual weeds but there is some filaree and an occasional small clump of perennial bluegrass.

Actually, however, the area is in far worse condition than it was seventenn years ago, despite its apparent improvement. The reason is that a foot or more of the soil that was there earlier is now gone. The darker streaks that now mark the surface of the hillside on both sides of the oak tree are the *bottoms* of the gullies that attempts are being made toward proper grazing. With nothing but sub-soil left however, it will be decades, if not a century or two, before the land will again support a satisfactory stand of vegetation and furnish any appreciable forage for livestock.

—FRED G. RENNER, *Washington, D. C.*

From Our Readers

DEAR MR. GUMBEL:

Some time ago, I read a letter in the JOURNAL from a man in Great Britain who was reluctantly dropping his membership in the Society because of the high cost—due, I presume, to the scarcity of American dollars. Then a few weeks ago, I received a letter from a friend in the Indian Government stating that soil conservation efforts on the part of his Government had practically come to a halt.

It seems to me that the Soil Conservation Society of America can do its bit in an active and direct way by suggesting that each Chapter sponsor *at least one or more* memberships to deserving and influential individuals in some foreign country, especially persons who, for some reason or other, find it a hardship to maintain membership. In my opinion, it is important to keep others besides Americans informed on the urgency of conservation and this might be a simple and direct way of helping out. It certainly would not hurt the prestige of the Society.

—ROSS M. MELLINGER, *Elizabeth, W. Va.*

DEAR MR. GUMBEL:

Your Book Review section is excellent as it gives to many readers a service that is seldom rendered. It calls to their attention not only the new books which are written on related fields of science in which they are interested, but also calls their attention to other important items than those in which they are specializing. Many professional scientists and research workers do not have enough time for extra reading and these reviews keep us all well posted.

—WILLIAM E. WARD, *Cincinnati, Ohio*

DEAR MR. GUMBEL:

The January issue commends itself so heartily to me that I am impelled to express to you my appreciation for your share in it. All of its articles were found to be worth my reading and a number were recommended for reading to others. *The reviews of books were so excellent that five of the books were ordered.*

—S. S. VISHER *Indiana University, Bloomington, Indiana.*

there's a **JOB** to be done

one that puts a premium on

VERSATILITY

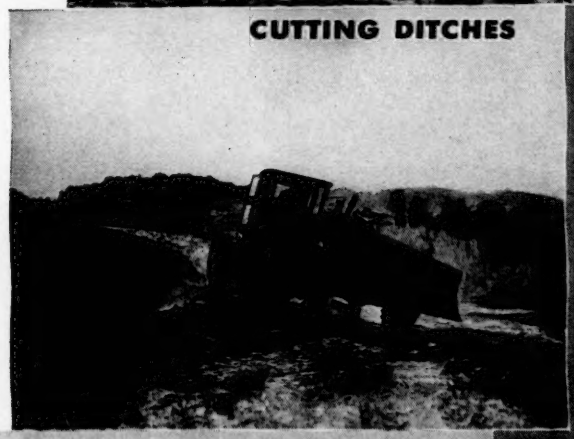
No single machine will do so many soil conservation jobs so easily, quickly and economically as the modern motor grader—especially an Austin-Western Power Grader with its exclusive All-Wheel Drive for maximum traction in rough or soft ground; 30% more "power-at-the-blade" and exclusive All-Wheel Steer for high speed turning and maneuvering in close quarters.

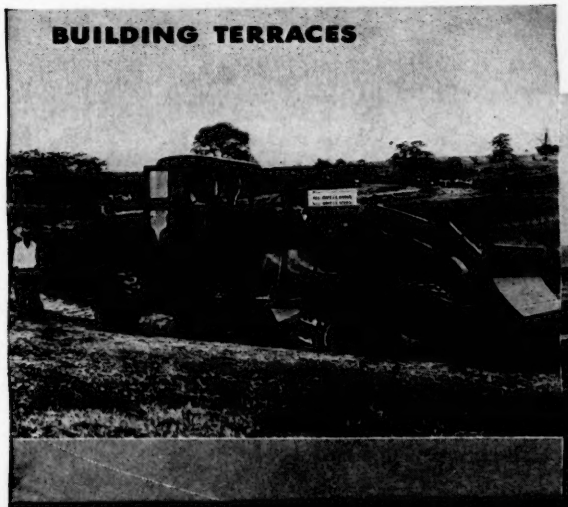
The bulldozer attachment has many uses... filling gullies, blocking the ends of level terraces, clearing out brush and small trees, etc.

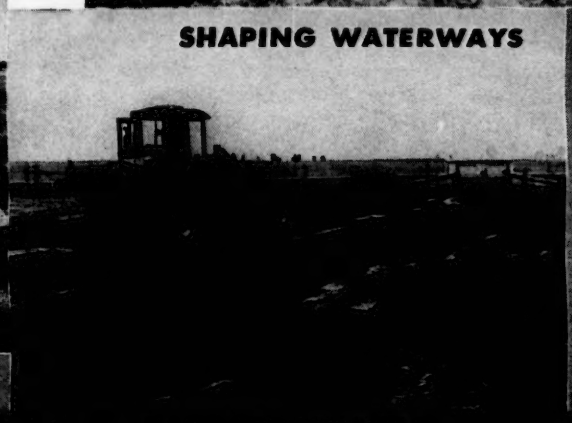
Yes, for all-around versatility, you can't beat an Austin-Western Power Grader, and it *gets the job done.*

AUSTIN-WESTERN COMPANY
AURORA, ILLINOIS, U.S.A.

FILLING GULLIES


CUTTING DITCHES


BUILDING TERRACES


SHAPING WATERWAYS

BUILDERS OF ROAD MACHINERY

Austin Western

SINCE 1859

Tommy plays the Tuba...

Now Tommy is no John Philip Sousa—not by a long shot. Fact is, Tommy himself would be the first to admit it, the first to point out that he's just an average high school youngster with a flair for music. But don't underestimate the lad. To the folks of his community, he's quite an important fellow.

Every Wednesday night, from May to September, Tommy totes his tuba to the town square. There his horn obediently blends a measured "oompah" to the voices of a score or so other instruments manned by Tommy's fellow citizens. There a local tailor cuts a melodic pattern from a trumpet of burnished brass; a vo-ag teacher exacts a tuneful lesson from a disciplined clarinet; farmers, merchants, tradesmen—all musicians on Wednesday night—join with Tommy in continuing a great American institution, the weekly band concert.

Dutifully they render their program—from stirring march to lively polka, from inspiring overture to latest hit tune. And then, as the last strains of the National Anthem are gathered in the arms of tall trees around the square, the applause registers for Tommy and his fellow bandmen the thanks of a grateful audience, a tribute to those who, like Tommy, know the value of community spirit and the joy of serving their neighbors.

* * * * *

Those who work on soil conservation are not unlike Tommy the tuba player; for soil conservation *American style* is the very essence of community spirit—community spirit in action.

JOHN DEERE • MOLINE, • ILLINOIS